FEILDEN'S MAGAZINE

An

ENGINEERING REVIEW

Edited by C. EDGAR ALLEN.

Vol. 9. OCTOBER, 1903. No. 4.

The Valve Gears of Modern Mill Engines.

PERHAPS in no class of engineering are there afforded better examples of design and workmanship than in the valve gear of the modern mill engine, and a short description of a few of the more recent types may prove interesting to many of the readers of FEILDEN'S MAGAZINE. It will be convenient, in the first place, to consider what are the essential features of a good valve gear suitable for an engine driving the machinery of a large modern spinning mill, from which it will be seen how excellently modern examples are adapted to their work.

The first point is economy, and in this respect the four-valve Corliss engine has no superior. The clearance space is small, the drainage of the cylinders is efficient, and there are separate passages for the entering and exhaust steam.

Close regulation is another essential feature of a high-class mill engine; and no type of engine can show closer regulation than a Corliss engine with automatic trip-gear, the work thrown on the governor, in regulating the degree of expansion, being so small that it admits of extremely sensitive governors being employed, which are, from the nature of their design, by no means powerful, and would be quite useless for the regulation of automatic expansion valves of the sliding type, of a size that would be necessary for a large engine.

Another desirable feature in this class of gear is that it shall be capable of bringing the engine to a stop in case of emergency, and this must be effected with ease from any desirable part of the mill.

The type of gear usually employed by English makers is the double eccentric Corliss trip-gear, which means that one eccentric is used to actuate the steam valves, whilst the other operates the exhaust. With the types of valve gear which are about to be described this allows of a wider range of governor control than would be possible were only one eccentric employed. Before the reason of this can be thoroughly explained, however, it will be necessary to consider the action of some forms of trip gear.

Amongst the first makers of Corliss engines in this country are Messrs. Hick, Hargreaves, Bolton, and the gear they now employ varies only in minor details from that made thirty years ago, which speaks well for the excellence of the contrivance, for the engines made by this firm can well hold their own with the more recent forms. Fig. 1 shows the tripping arrangement, which consists of a short rod *A*, to which are bolted two spring steel clips carrying hardened steel catches, or nibs, which engage with similar catches secured to a socket rod *B*, of which the end *D* is coupled to the

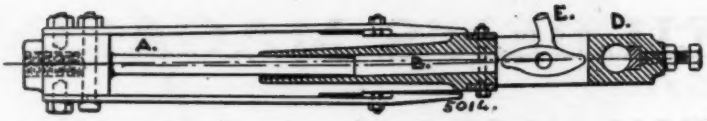


FIG. 1.—TRIPPING ARRANGEMENT MADE BY MESSRS. HICK, HARGREAVES.

steam valve lever. At certain periods the toe lever *E* opens the spring clips, and the catches thus being free the dashpot is enabled to close the valve. The governor acts upon *E*, varying the instant at which the catches are released. The general arrangement of the gear made by Messrs. Hick, Hargreaves is clearly shown in the annexed illustration, Fig. 2. It will be seen that two wrist-plates are employed. The governor connections can be clearly traced. The two small levers over the centre of the wrist-plates, and which are carried by the dashpot, are keyed to short spindles on which are fastened small toothed sectors, so that although the governor is only connected to one of the levers they have both an equal movement, but in opposite directions. The toothed sectors are not seen in the illustration, but they lie almost directly under the centre of the dashpot. This equal and opposite movement of the governor trip levers is essential to most trip gears, though there are other ways of obtaining it. Two common arrangements are shown in Fig. 3. In the first diagram the two rods moving the catch-levers are connected to opposite ends of a double-ended or beam-lever on the governor fulcrum spindle, and in the other case one rod from the governor connects to a double-ended lever placed on the centre line of the cylinder; and from this double-ended lever short rods pass to the catch-levers. The latter is the neater arrangement, and is the one mostly employed by English builders. Referring again to Fig. 2, it will be seen that the governor is in the bottom position; and when in this position it will adjust the toe-levers so that cut-off is somewhere about 75 per cent. of the stroke. As the governor rises the toe-levers are moved so that they open the clips earlier in the stroke, and when the governor attains its highest position the valves are tripped before the lap has been worked off, consequently the steam is entirely shut off from the cylinder. Now, it is not a difficult matter to design a governor for such a light duty as moving two small trip-levers that shall rise from its lowest plane of revolution to its top position, with an increase of two per cent. in the speed, so that it will be understood that, given a sufficiently heavy flywheel, the speed regulation can be made extremely close.

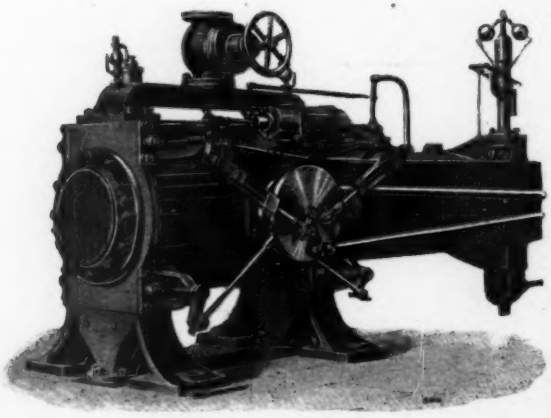


FIG. 2.—GENERAL ARRANGEMENT OF GEAR MADE BY MESSRS. HICK, HARGREAVES.

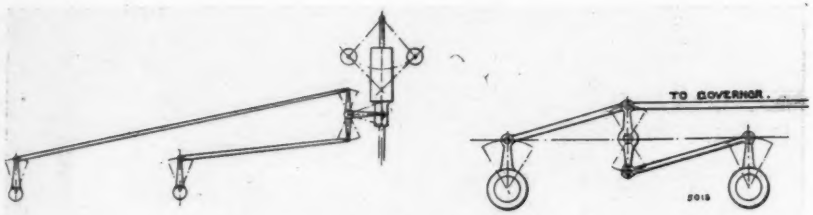


FIG. 3.—GOVERNOR TRIP-LEVER ARRANGEMENTS.

Messrs. Cole, Marchent & Morley's improved Spencer-Inglis slip-rod is shown in the next illustration (Fig. 4). The objects sought in this arrangement are to avoid the sagging which sometimes occurs in the ordinary gear, and to render the parts which fly with the dashpot as light as possible. To this end the sliding piece is centred and balanced on the valve-lever, and when in extreme position, as shown in the figure, the rod passes through almost the whole length of the sliding-sleeve. The next Fig. (5) shows the gear side of one of this firm's engines fitted with their improved trip motions. Although the present engine is for electric driving, it will serve to show the general gear arrangement that obtains with a high-class mill engine. In operation this gear is practically noiseless, and will run with a certainty of engagement up to speeds of 120 revolutions per minute.

The Spencer-Inglis gear, it will be noted, has two wearing nibs for each valve, a feature possessed by few other gears, and one that must add somewhat to life of the catches. In addition, the catches are reversible, so that when one edge is worn they can be turned to present a new edge.

The Dobson trip gear, made by Messrs. Yates & Thom, is shown in Fig. 6. It consists of a moving slide *E*, carrying the trip-catches *A*, and the trip-levers *B*. The governor is connected to the rod *C*, which moves the double-ended lever *D*. The dashpot is stationary, being bolted to the carrier bracket, and forms a guide for the slide *E*. Now, assuming the trip-levers to be held in a certain position by the governor, the effect of moving the slide *E* a sufficient distance to the right will be to allow the catch-piece *A* to drop upon that part of the dashpot trunk marked *F*. The gear is designed so that the catch-piece *A* moves about a quarter of an inch past the steel piece *G*. The slide *E* then returns, and in doing so drags the dashpot piston, trunk, and catch to the left, against the resistance of the dashpot spring, because the catch-piece *A* bears upon the edge of the catch *G*. This state of things will continue until the trip-levers *D* lift the catch-piece *A* clear of *G*, when the dashpot piston immediately flies back to the end of the chamber. A small valve at the end of the chamber regulates the escape of air, and serves to break the impact of the piston on the end of the chamber. As the governor rises it will move the trip-levers inwards, the effect of which is to lift out the catches earlier in the stroke. The small projections *H* are useful in case of a breakdown of the springs, when they serve to bring the valves into a closed position. The exhaust gear is also shown, as well as the form of the valves and the disposition of the ports. Both steam and exhaust valves

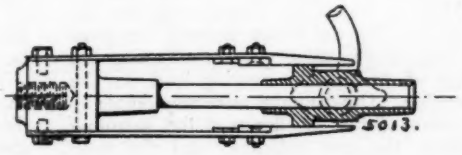


FIG. 4.—IMPROVED SPENCER-INGLIS SLIP-ROD.

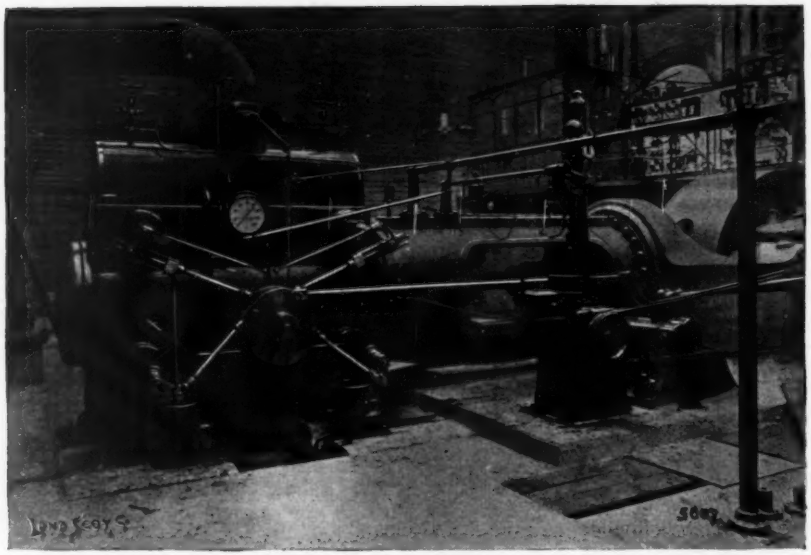


FIG. 5.—HIGH-PRESSURE CYLINDER FITTED WITH MESSRS. COLE, MARCHENT AND MORLEY'S IMPROVED TRIP-GEAR.

are double ported, whereby the necessary movements are reduced and the exhaust valves are made to take up as much of the clearance space in the valve chambers as possible without hindering the free egress of steam from the cylinder. It will also be noted that there are no stuffing boxes on the valve bonnets, the joint being made by a conical bush on the spindle rubbing against a corresponding ring in the bridle, the steam pressure acting endways on the spindles furnishing the necessary force to keep the surfaces together. Fig. 7 is a perspective view of one of Messrs. Yates & Thom's horizontal tandem compound engine, with trip gear on the high-pressure cylinder.

Some diagrams taken from one of Messrs. Yates & Thom's engines inspected by the writer showed the great range of the valve gear in adjusting the cut-off to suit the varying load on the engine. The diagrams were remarkable by reason of the excellence of the steaming lines, the free exhausts, and the well-defined cut-off corners.

Messrs. Victor, Coates & Co., Ltd., are also makers of the Dobson trip gear; and Fig. 8 is a reproduction of a working drawing of the motion specially adapted for a vertical engine. It differs in detail from the previous example chiefly in the method of connecting the valve-rod to the dashpot piston. In the present example the rod is flattened in order to allow sufficient flexure to accommodate the versed sine of the valve-movement arc. The other plan is to provide a ball joint for the valve rod. The projection on the valve lever (Fig. 8) is for the purpose of lifting the catches into gear when starting, by means of a lever provided with a socket to receive the projecting piece. In Messrs. Yates and Thom's gear a square is formed on the end of the valve spindle, and a key provided to fit it. The square can be seen by an inspection of Fig. 7.

A complete set of diagrams of one of Messrs. Victor, Coates & Co.'s engines, indicating upwards of 1,000 h.p. on a piston speed of 560 ft. per minute, inspected by the writer showed excellent steam lines, as

well as well-defined compression corners, showing that the clearance volume is small. The intermediate and low-pressure cylinders, drawing the steam from their respective receivers, had of necessity sloping steam lines; hence the rapidity of the cut-off is not so clearly defined. The remarkably small steam consumption of 10·13 lbs. testifies to the excellence of design and workmanship of the engine.

The gear made by Messrs. Ashton, Frost & Co., Ltd., Blackburn, is a modified form of Dobson gear, the chief difference being in the method of lifting out the catch pieces. The long bent trip-levers, to which the governor is connected, carry a small roller at an intermediate point, which, striking the short bell-crank levers in the trip boxes, lifts out the catches. As the governor rises, the upper ends of the trip-levers move inwards and cut-off is earlier. The general arrangement of the gear is clearly shown in Fig. 9, an inspection of which will show that the design has been well thought out. Both steam and exhaust valves are driven through the medium of rocking levers, which, however, have no effect on the valve movements, like that of a wrist-plate, and are merely provided so as to avoid inordinately long eccentric rods. The makers state that this gear has run successfully at ·135 revolutions per minute.

The chief difference between the Dobson gear and its modifications and the gear made by Messrs. Hick, Hargreaves & Co., and Messrs. Cole, Marchent & Morley, is that the latter is provided with wrist-plates. Besides being necessary to carry one end of the slip-rods, these wrist-plates impart a peculiar motion to the valves, which, in addition to reducing the stress on the rods and other parts, renders the valve action more in accordance with the requirements of the varying velocity of the piston. This will be better understood by referring to Fig. 10, which shows the centres of motion for a wrist-plate gear. The extreme positions on each side of the centre of oscillation are shown by dotted lines, from which it will be seen that the wrist-plate swings 26 degs. on each side of the central position *A*, but during that half of the motion from

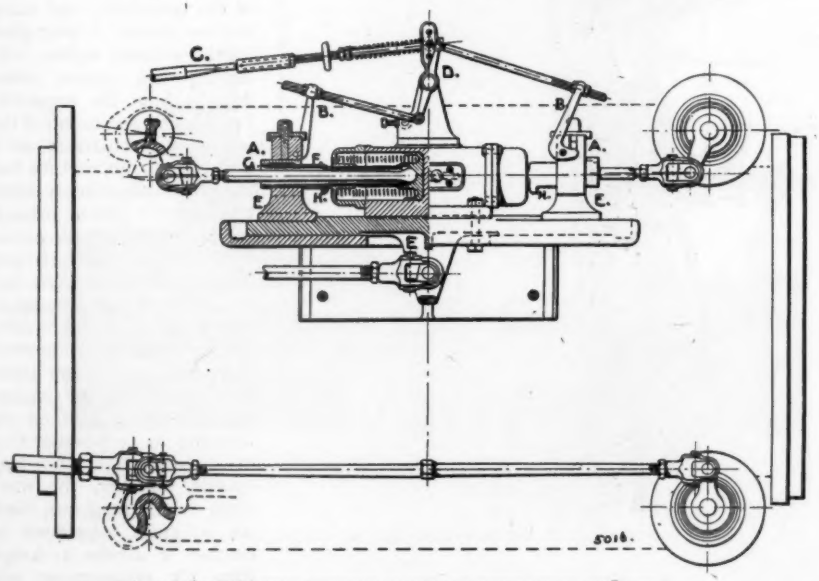


FIG. 6.—THE DOBSON TRIP-GEAR AS MADE BY MESSRS. YATES AND THOM

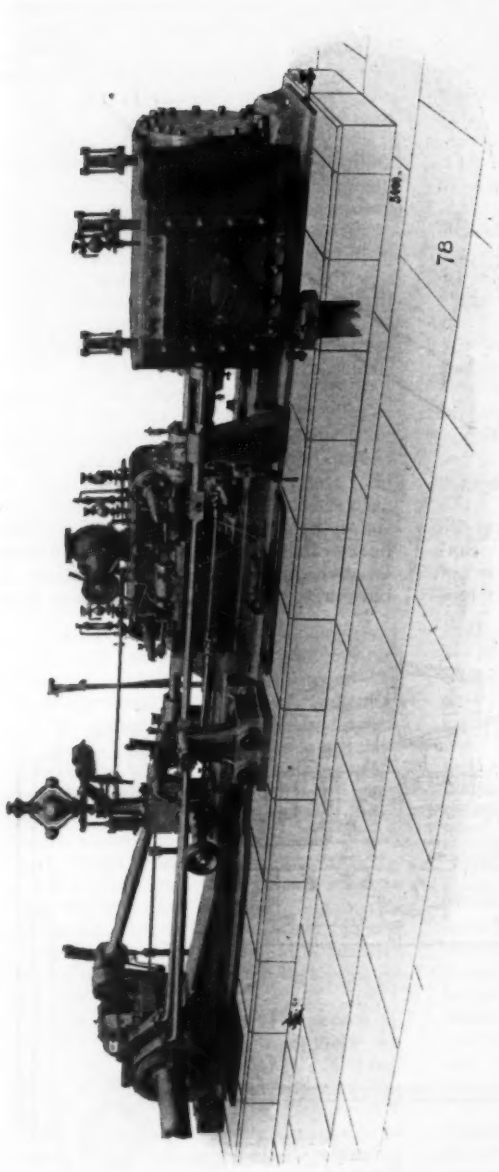


FIG. 7.—ONE OF MESSRS. YATES AND THOM'S COMPOUND ENGINES WITH TRIP-GEAR ON THE HIGH-PRESSURE CYLINDER.

A to *B* the valve lever moves 25 degs. only, and during the other half of the wrist-plate movement it moves 41 degs. At the commencement of the wrist-plate movement the valve covers the port by the amount of lap, and until this lap is worked off the greatest pull is required to move the valve, because it is unbalanced; but as soon as the lead is given the gear is considerably relieved, and at the same time the nature of the valve movement is changed from a sluggish to a rapid action, thus giving a copious steam opening for the increasing velocity of the retreating piston. The wrist-plate action is also very useful in the case of exhaust valves, since it enables a wide and rapid opening to be given without an excessive travel of the eccentric; and some makers provide a wrist-plate for the exhaust valves only, driving the steam valves straight from the eccentric. During one revolution of the engine each exhaust valve performs no function for half the cycle, and is simply dwelling over the closed exhaust port; and it is this idle period which throws most work upon the gear, hence the advantage of reducing the amount of this dwelling or idle motion. On the other hand, the wrist-plate introduces extra joints in the gear; so that engine-builders are divided on the question as to whether they are an advantage. For high speeds, however, the wrist-plate is advantageous, since for a given clearance of catches it allows a longer time for engagement, and

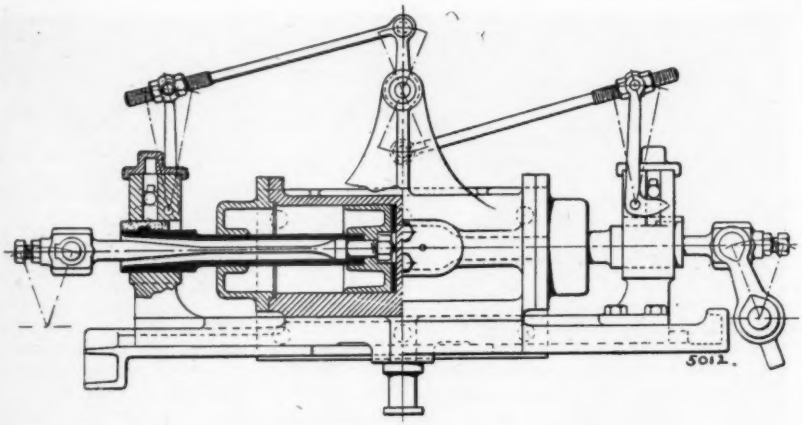


FIG. 8.—THE DOBSON TRIP-GEAR AS MADE BY MESSRS. VICTOR, COATES AND CO.

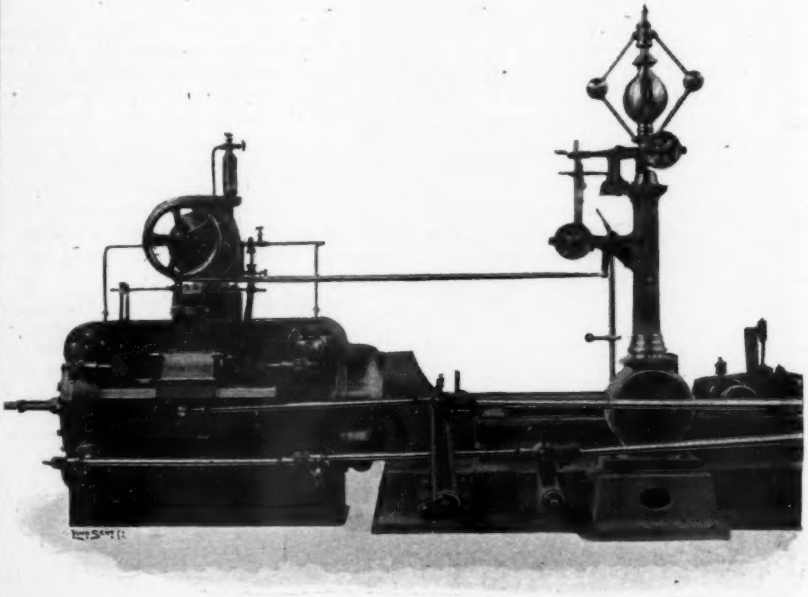
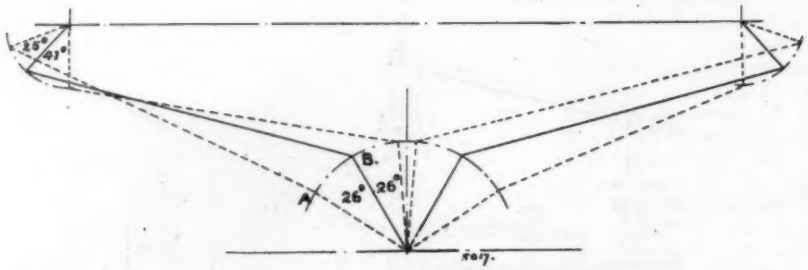


FIG. 9.—GENERAL ARRANGEMENT OF GEAR AS MADE BY MESSRS. ASHTON, FROST AND CO., LTD.



G. 10.—DIAGRAM OF CENTRES OF MOTION OF WRIST-PLATE GEAR.

the striking velocity of the tripping edges is reduced.

The next diagrams (Fig. 11) illustrate the relative positions of crank and eccentrics for single and double eccentric gears. In the first diagram the eccentric is in advance of the crank by a somewhat greater angle than 90 degs. In the double eccentric gear the steam eccentric is about 35 degs. in advance of the crank, and the exhaust about 135 degs. Now a study of any of the gears that have just been illustrated will show that the trip-levers can only lift out the catches when the valve-lever is moving the valves in the opening direction, and referring to the first diagram it will be seen that the crank has less than 90 degs. to move before the eccentric begins to return, hence the range of tripping is less than half-stroke. In the second diagram the range is considerably increased, and the eccentric does not begin to return until the piston has reached about 75 per cent. in the stroke. Of course, such a position of eccentric as that shown in the diagram for the double eccentric gear is unsuitable for controlling the exhaust gear, hence the necessity for two eccentrics. The diagrams also show how the lap, lead, and clearance of catches govern the angle of the eccentric.

In all the examples previously given the spring dashpot is used. In America and on the Continent vacuum dashpots are largely employed, but most English makers prefer the spring type. The latter type has this advantage, that some adjustment is obtainable, so that, should the dashpot be found sluggish in its action, a washer inserted between the end of the spring and the cover will give an increased pull on the valve-lever, or, should a washer be deemed undesirable, a new spring can be fitted at a trifling cost.

The fine engines shown in Fig. 12 are by Messrs. Wood Brothers, Sowerby Bridge, Yorkshire. The valve gear is a

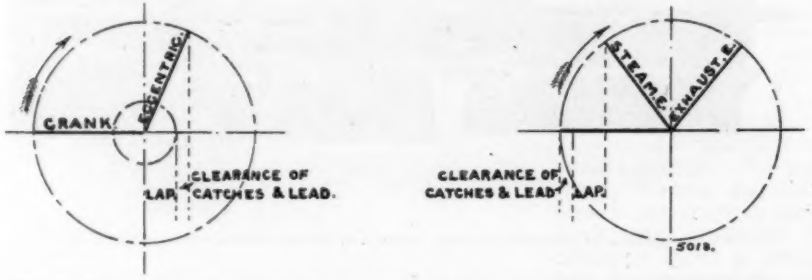


FIG. 11.—SHOWING RELATIVE POSITIONS OF CRANK AND ECCENTRICS FOR SINGLE AND DOUBLE ECCENTRIC GEAR.

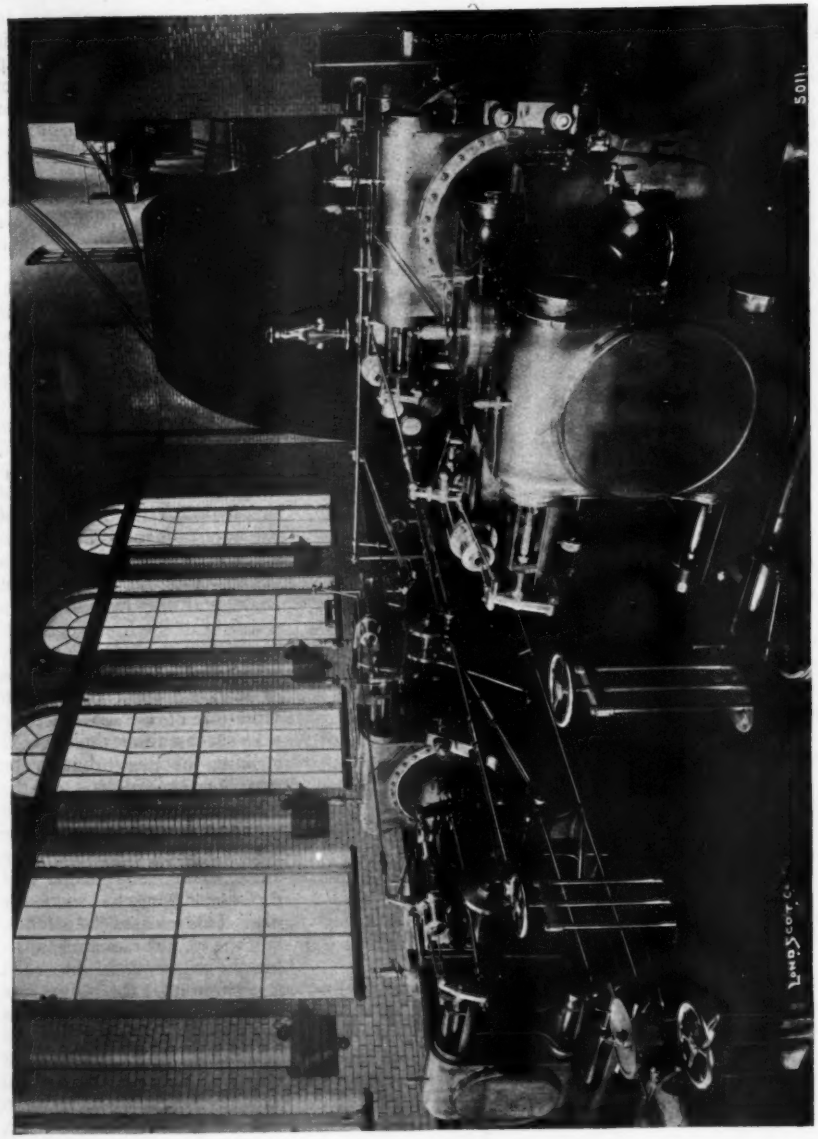


FIG. 18.—ENGINES WITH MODIFIED FORM OF CRAB-CLAW VALVE-GEAR BY MESSRS. WOOD BROTHERS.

modified and improved form of crab-claw gear, and is very simple in design. The outer double-ended levers, to which the dashpot rods are attached, are keyed to the valve spindles and carry a square piece on their lower ends, with which the crab-claw catches engage. The release is effected by a projection on the inner levers, to which the governor rods are connected, striking the crab claw.

Wrist-plates are employed for the steam valve-rods, but their object is to carry the ends of the claw rods rather than to modify the valve movement, for, from the position of the wrist-plate pins, it will be seen that little modification of the eccentric motion is effected. This gear, together with a few others, has an advantageous feature in that the trip-levers are not in continual motion. In the Spencer-Inglis and Dobson gears, for instance, the trip levers are always oscillating by reason of their connection with the valve-rod or trip box, the governor merely altering the position of the levers. Here, however, the trip-levers are stationary except for the slight motion they receive from the governor. The well-known Reynolds gear may also be cited as an example in which the trip-levers are practically stationary.

The next point to consider with reference to the valve gear of mill engines is the means of bringing the engine to a stop in case of accident, and Fig. 13 shows a common form of automatic knock-off gear. The end *A* is fixed to the governor, and moves the trip-levers through a convenient arrangement of linkwork. The lower end of the knock-off rod is hung upon catches, which have usually a slight undercut to prevent accidental slipping, and carries a weight at the lower end. *C* and *D* are two stops or pegs, which, in ordinary conditions of working, allow the normal vibration of the governor to take effect without the finger *E* striking the pegs; but in the case of breakdown of the machinery, whereby the load is suddenly thrown off the engine, the governor rises above its normal plane, and the finger strikes the lower peg. This releases the catches, and the weight descends, moving the tripper rods into such a position that the valves are tripped before the lap is worked off; hence, no steam is admitted to the engine. At the same time the fall of the weight opens a small valve in connection with the condenser, which destroys the vacuum. On the other hand, a sudden

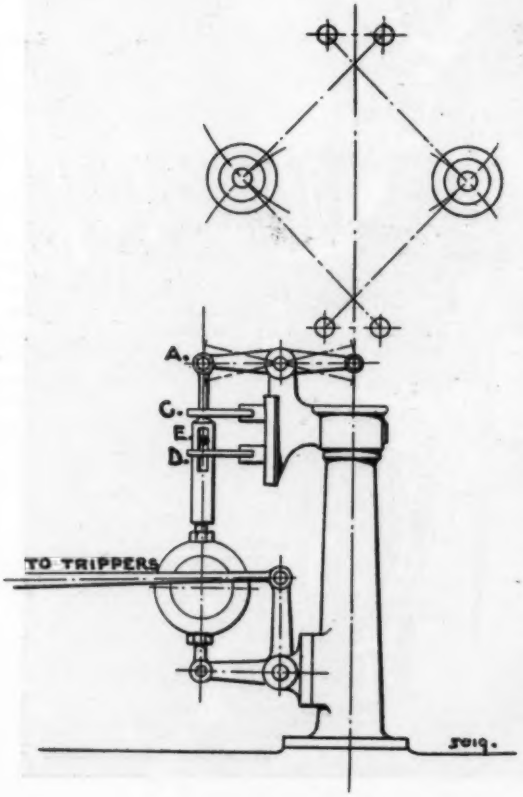


FIG. 13.—AUTOMATIC KNOCK-OFF GEAR.

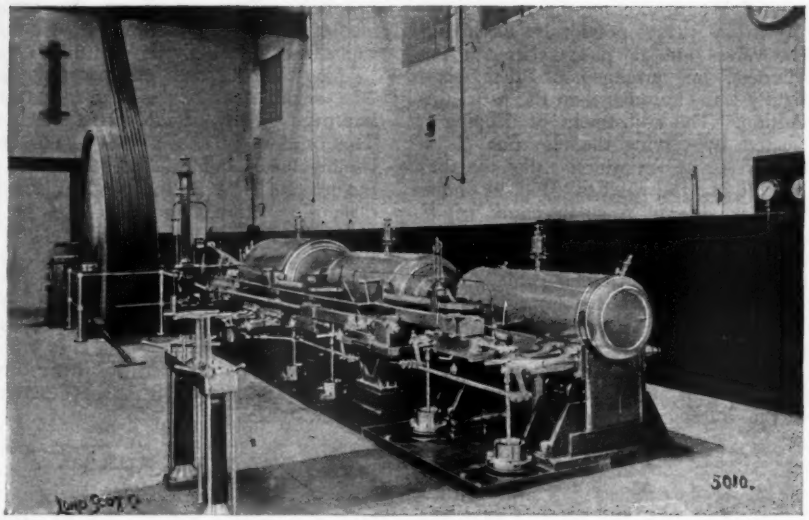


FIG. 14.—ENGINE AND VALVE-GEAR BY MESSRS. JOHN AND EDWARD WOOD, BOLTON.

decrease in governor speed, due, say, to the breakage of the governor ropes or driving gear, or to the seizure of one of the main journals of the engine, causes the finger to strike the upper peg, releasing the catches as before. Slots are usually provided for both pegs, so that the automatic knock-off can be arranged to act at any desirable speed above or below the normal. The low-speed peg is generally made removable, and before shutting off steam at the stop valve it is removed, and thus allows the governor to settle down in the bottom position without disengaging the catches. On starting again, the peg is not replaced until the normal speed is attained and the finger falls below the point where the peg is inserted.

Sometimes a knock-off arrangement is provided in connection with a rope alarm, an apparatus consisting of a light, brittle lath of wood, carried by supports close to face of the rope pulley. In the event of unravelling of the ropes, due sometimes to defective splicing or breaking of the strands, the frayed and loose ends strike the lath and break it, thus releasing a weight or spring, which moves the tripping levers, so that no steam enters the cylinder.

An automatic knock-off gear is applied to most of the engines that are illustrated in this article. The parts being small, however, do not come out very distinctly; but in the engine by Messrs. Ashton, Frost & Co., the gear is clearly seen fixed near the governor stand.

When the trip-levers are operated from various parts of the mill, a simple electrical apparatus is employed. A magnet-box is placed so that on making a circuit a finger strikes the catches out of gear, and by locating pushes in various parts of the building the engine can be stopped in case of emergency without loss of time.

In Tate's well-known electric stop-motion a powerful coiled spring is attached to the stop-valve spindle, which closes the stop-valve when an electric circuit is made, the pushes being placed wherever it is deemed desirable. The apparatus can also be made to work directly on the trip-levers.

The gear made by Messrs. John &

Edward Wood, Bolton, differs considerably from those previously described. The valves are all placed beneath the cylinders, an arrangement that gives slightly less clearance than the usual disposition. The adjustment of tripping is effected by varying the elevation of an inclined plane, on which strike the dies that lift out the catches. Fig. 14 shows the gear side of a single-crank triple-expansion engine by this firm, and gives a good idea of the valve arrangements. The low-pressure cylinder—which, it will be noticed, is placed foremost—is not fitted with trip-gear, the valves having a simple oscillating motion derived directly from a single eccentric; and this eccentric also serves to actuate the exhaust valves of the intermediate and high-pressure cylinders. The cut-off on the intermediate cylinder is adjustable by hand, whilst the governor has control of the tripping on the high-pressure cylinder. The engine is fitted with the makers' improved gravity-loaded spring dashpot. The bridles are shown with glands and stuffing boxes, but the recent practice of the makers is to fit the cone-bush, thus dispensing with soft packing.

Having now described some of the best Corliss gears in use at the present time, it only remains for the writer to thank those firms who have so kindly placed the details of their engines at his disposal; and whatever interest or value lies in this article is to be ascribed to those firms whose manufactures are here described and illustrated.

CHARLES HURST.

Trouble Prevention on Electric Mains.

In nine towns out of ten, the mains give more trouble than all the rest of the station equipment put together, and it is safe to say that this trouble could be obviated almost entirely by the expenditure of a little more thought and money at first than is usually given to them, and, later, by a proper system of management.

Central station engineers of experience know which is most to be feared: a nut in a cylinder, a burst boiler-tube, or a short circuit on the outside network. Disasters inside a works can be remedied promptly; spare plant is run up, the defect on the machine can be seen and got at, if necessary, immediately, or it can be left until a more convenient time, and all is happy generally within an hour or so of the most awkward station accident. With mains, however, the defect may be anywhere in the town and suburbs; the weather may be anything, but the spot must be found, and at once.

Then arises a frenzied rushing about with spanners, and spades, and saws, and ohmmeters; much hurried consultation over dirty diagrams in thumbed and dog-eared notebooks; and a general cutting about of good cables, with repairs of an evanescent description, which sooner or later develop into first-class faults themselves.

Now all this unnecessary and wasteful exertion could be saved but for three things: the provision of unsuitable cable in the first instance; the non-provision of proper accessories; and the lack of knowledge of, or carefulness with, mains on the part of the responsible engineer and his men. Where these difficulties are overcome, in that town is the electricity supply in the blessed condition of having no history, and of being a source of profit to its owners.

It is the writer's intention to touch upon some of the details which go to produce this enviable state of things, and a few of the following hints may perhaps be of use to central station engineers in charge of networks.

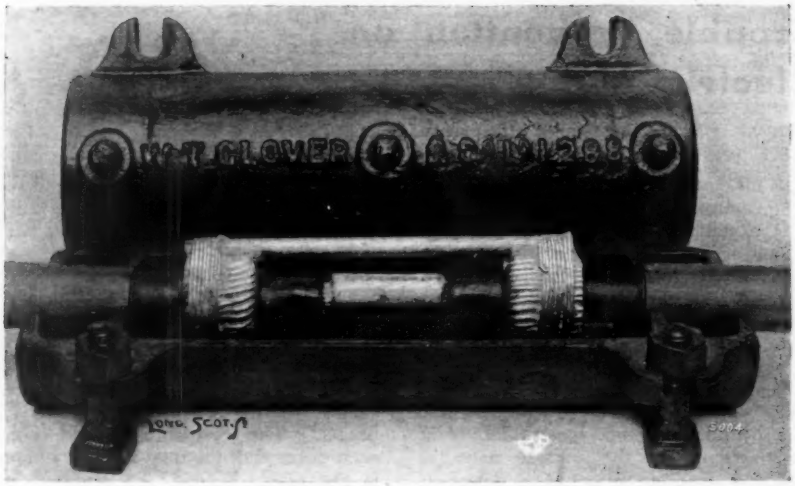
Duplicate Feeders.

This does not mean a duplication of the cost, however, but is merely an exemplification of the proverb that warns against putting all one's eggs into one basket. The cost of using two cables, each of one-half the total section required, is not much beyond the price of one cable of the full section necessary, and this extra expense should be looked upon as a sound insurance investment, just as spare machinery is put down at the works.

The method of working the duplicate feeders would be identically the same, under ordinary conditions, as with one full-size cable only. The advantages would be double, however, inasmuch as during light working hours regular tests could be made upon one of the cables, disconnected at both ends, which would do much towards preventing breakdowns. And when the unpreventable occurred upon either main, the other could do the work efficiently at light load periods (which is the major part of the day) and at full load would merely provide a dimmer illumination, which is proverbially better than no light at all.

Mr. L. Andrews, for so long the Hastings Corporation Electrical Engineer, recognised the usefulness of this duplicating arrangement some years ago, and has devised an apparatus for improving the system so as to prevent the slightest interruption to the circuit when a duplicated feeder breaks down. For many cases, however, a little applied common-sense will suffice to ensure practical working.

Duplication need not be confined to



CONCENTRIC SOLID JOINT BOX.

feeders; but, owing to the greater facilities for cutting off sections of distributors without interrupting the general supply, it is not so necessary for the network.

Disconnecting Facilities.

There are three kinds of arrangements in vogue. One is solid joints everywhere, with no fuse or link from switchboard to consumer's cut-out. This type is founded upon distrust of exposed insulation, and is sustained by the Doctrine of Luck. When anything goes wrong on a system of this description, there is more trouble than enough.

Another type is of the nature of a compromise with disconnecting boxes (which take hours to get at the fittings) scattered here and there, with no standard sizes of fuses or links, and which generally cause more trouble and bad language than they prevent.

The third type is the system laid out by experienced mains men from the beginning, in which a standard roomy make of disconnecting box is used at all joints, with all nuts and bolts, links and fuse-handles, also surface and pillar-box keys interchangeable; where every facility is given for quickly and safely disconnecting for testing, or for locating breakdowns; where all manholes are large enough to work in comfortably, and where all cables are slung up in order, labelled and painted in the manholes for easy identification. This, then (although it will seem like an unattainable Paradise to many mains engineers), is the most satisfactory system, and taken in conjunction with the other points mentioned in this article should go far towards preventing trouble from such accidents or carelessness as are impossible to guard against.

Jointing.

Emphasis should be laid upon employing good men only, and the necessity of keeping an eye on them. The principal cause of trouble upon mains is defective jointing, and even good jointers may have wrong ideas about some parts of their work, which only need noticing for the mains engineer to put right.

The joint fittings themselves are frequently to blame for bad joints. Some makers supply a class of sleeve for the outers of concentric cables which depend for contact upon a dead accuracy of fit

and extreme care in soldering. In case of the fit being slack or tight, screw-pressure is put upon the insulation between the inner and outer; and should the soldering be clumsily done poor contact is made, or solder points are left sticking in the insulation. A class of joint is shewn in which it is impossible to make poor contact or to injure the insulation by pressure. The outer sleeve is quite loose over the concentric conductor, but conductivity is perfectly obtained by the ends being brought back over the outside of the sleeve and bound with fine copper wire over both the sleeve and the connecting-rod. This may be further sweated if the joint is to work under oil. A jointer's chief need, however, is a conscience; and with this in efficient working order he cannot do much harm.

Testing.

It is the custom to decry insulation tests, and certainly a solitary occasional test upon a cable is nothing to go by, especially if the cable is a newly laid one. When, however, weekly tests are taken upon all cables and reproduced diagrammatically, the most useful results accrue. No cable can tread the downward path very far without showing its degradation on a galvanometer; and should the falling line on a diagram be the result of a few periodical tests, the trouble can be grappled with and remedied before anything serious happens.

The piece of cable that is showing signs of faultiness can be discovered on a length or network by disconnecting at the link-boxes and insulation testing. Where facilities for disconnecting are not provided, a double-pressure test will often help to locate by breaking down the poor insulation to a dead short or earth, when either more elaborate tests with a Wheat-

DISCONNECTING BOX.

stone bridge can be used, or the locality determined by noting where fuses blow.

Extensions.

The foregoing are general remarks which may be applicable to many systems now working. With regard to extensions or the laying-down of new mains, the following are the writer's opinions as to the best system :—

Single-conductor cables should be used on direct currents, laid in pitch or bitumen, with stout wood or asphalt trough and tiled or concrete top for protection. A clearance of half-inch of compound to be all round cables where wood is used. The bearers to be well boiled in pitch.

For alternating or high-tension work, multicore paper-insulated lead-covered cables are best, laid also on the solid system.

Joint these cables with the maker's tapes or boxes, and to their instructions, taking care that your jointers follow the same religiously.

Joint-boxes should be used at services and should have links for disconnecting purposes, made of either glazed stoneware or cast iron lined with asphalt, to prevent any chance of earthing. A porcelain

SCENE IN WORKS ON BREAKDOWN OUTSIDE BEING ANNOUNCED.

partition to be between the links and the box filled with insulating compound up to the links, and a layer of paraffin-wax melted over them. This wax makes a cleaner job than oil, and is easier to get at in a hurry. Disconnecting-boxes should be used at all main junctions and at every quarter-mile of straight run, materially arranged as the service box mentioned, but preferably a separate box for each set of poles to prevent shorts.

Manholes should be roomy and dry, with the cables running through them kept well away from under the opening, so that the jointer's mate may find no convenient resting-place upon them. The cables should be cleated to the walls, or otherwise well supported.

Precautions against Breakdown.

Beyond an initial double-pressure test and an occasional insulation test, there is usually nothing much done in the way of anticipating the inevitable burst up that will happen even upon the best regulated mains.

A practical idea might be borrowed from the Fire Brigade's book, and that is to have alarm practice—say on Sundays. Let the engineer deliberately earth or short-circuit a disconnecting joint at a place unknown to his men, and set them to locate it, with only the mute indications of the switchboard instruments to guide them. A few trials at this would help a great deal when the grim reality came along, as it usually does at the most inconvenient time.

A few breakdown carts would be of great service if kept at suitable situations. Each should consist of a light two-wheeled covered truck, containing a test set, jointer's tool bass, set of manhole keys, disconnecting spanners, rubber gloves and mats, picks and spades, tarpaulin cover, and with a plan of the mains pasted on a board, varnished, and hung inside the cart for reference. The provision of these carts would prevent the state of confusion that occurs when tools are required in a hurry, but it would be necessary to have a distinct understanding about these carts being used for breakdown purposes only.

Summary.

For all these precautions money must be expended, and here is where the average responsible engineer becomes diffident, and remains content to take the risks. All who are thus faint-hearted certainly regret it in time. The amount spent in extra wages on half-a-dozen breakdowns will easily pay the cost of any extra apparatus or alterations that would have prevented such breakdowns and later ones, and the ensuing loss of customers is seldom properly known or appreciated.

At the same time the expenditure of money alone will never quite make for complete success. It is the bestowal of proper care upon the mains when being laid, and the intelligent inspection of same when working, that combine to make the perfect system that is known at present to quite a select body of mains engineers.

J. H. C. BROOKING, A.M.I.E.E.

The Restoration of Dangerously Crystalline Steel by Heat Treatment.*

THE researches of Brinell, Tschernoff, Le Chatelier, Heyn, Ridsdale, Stead, and many others have completely demonstrated that when steel of coarse structure, but not necessarily brittle, is heated to a certain temperature and is then allowed to cool in the air or is quenched in oil or water, the original structure is destroyed and is replaced by one of a very fine character. It was in 1898 that one of us fully demonstrated that pure iron, when coarsely crystalline and of exceedingly brittle character, resembling cast zinc more than any other metal, by heating to the critical point or just above the critical point, Ac3 (870 degs. Cent.), was restored to very excellent qualities so as to resemble the same iron in the condition in which it left the rolls.

Having for several years devoted much time and attention to the effect of heat on the mechanical properties of steel, and having repeatedly restored dangerously crystalline steel in large pieces by simple heat treatment, and obtained material which would be accepted by any engineer in the country as excellent, we thought that an account of our work would not be without value to this Institute, and would probably tend to show that the so-called generally received impression, that dangerously crystalline material must be forged in order to restore it to good qualities, is, excepting in rare cases, quite unfounded.

Varieties of Dangerously Crystalline Steel.

In the course of our experience we have met with steel dangerously crystalline which may for convenience be divided into three classes.

The first class occurs only in mild steel very low in carbon and in pure iron; it is caused by annealing for a long period at too low a temperature in a slightly oxidising atmosphere.

The second class, which is equally dangerously crystalline and is very common, is produced by long continued heating at high temperatures.

The third variety occasionally met with is produced by heating the steel till it is practically burnt. In other words, to a point so near fusion, that an evolution of gas occurs in the interior of the steel which separates the crystals from each other, so breaking up or making more or less discontinuous the whole mass.

The metal in the third class, although greatly improved by heat treatment, can never be thoroughly restored by simply heating it; but in the case of the steel of the first and second classes we have found no difficulty, by proper heat treatment, in making it equal and more often superior to the normal or forged steel which had been worked and finished at proper temperatures.

It is scarcely necessary to refer more than briefly to the restoration from brittleness of mild steel, as this has already been discussed in a paper by one of us in 1898, and by Mr. C. H. Ridsdale in the same year, the results of which have been fully confirmed by Professor Heyn of Charlottenburg, whose researches are contained in the proceedings of this Institute. We have, however, supplemented the work previously done by determining the resisting properties of the restored soft steel to continuous reversal of stresses.

The more recent work described in this paper has been confined to medium or structural steel, such as is generally used for the manufacture of rails, tires, axles, etc.

Experiments on Rails.—As exception has been repeatedly taken to experiments having been made upon small pieces of steel, and allegations made that if larger

* Paper read before the Barrow meeting of the Iron and Steel Institute.

masses were to be used the results would be quite different, we therefore made a series of experiments on rails of various sections. These were tested—first, in the normal state; secondly, in the dangerously crystalline state (a condition readily produced by heating the steel to between 1200 degs. and 1300 degs. Cent.); and thirdly, after such brittle material had been reheated to temperatures between 850 degs. and 900 degs. Cent., and allowed to cool in air.

The tests applied were as follows:—

1. Chemical analysis.
2. Impact or falling weight test.
3. Tensile test.
4. Brinell impression test.
5. Vibratory stress test.
6. Microscopic examination.
7. Specific gravity.

The results obtained are as follows:—

Series "A."

Bull head rail, 80 lbs. per yard, manufactured from hæmatite iron by the acid Bessemer process.

Analysis.

	Per Cent.
Carbon	0·43
Manganese	1·01
Silicon	0·05
Sulphur	0·094
Phosphorus	0·065

A1.—This was a complete rail, 30 ft. long, and had been allowed to cool down in air without treatment. This rail was subjected to an impact destruction test:—

Weight of ball ...	2240 lbs.
Distance of drop ...	20 ft.
Bearings apart ...	3·5 ft.
Length of rail tested ...	5 ft.

Fourteen blows were given, the rail being reversed after each blow, and not showing any signs of fracture. It was then nicked and broken. This result confirms previous evidence that high sulphur or about 0·1 per cent. is not objectionable in sound steel rails.

A2.—A short piece was cut from the rail at the conclusion of the above test. This was overheated for 2½ hours at 1260 degs. Cent., and allowed to cool down in the air, and was divided into two equal parts.

A3.—Part of the reheated rail "A2." This was slowly heated to between 850 degs. and 900 degs. Cent., and allowed to cool down in air, and was kept at that temperature in the furnace 40 minutes.

A4.—A piece of the original rail, 5 ft. long, was rapidly heated to a temperature of 1100 deg. Cent.; it was left in the furnace for 12 minutes, and was then allowed to cool down in the air. When cold it was tested to destruction by the impact test:—

Weight of ball ...	2240 lbs.
Distance of drop ...	20 ft.
Supports apart ...	3·50 ft.
Length of rail tested...	5 ft.

Eighteen blows were given, the rail being reversed after each blow. The rail broke at the nineteenth blow.

No. of Experiment.	Treatment.	Yield Point Tons Per Sq. In.	Ultimate Stress. Tons per Sq. In.	Elongation per Cent. in 4 ins.	Contraction of Area per Cent.
A1	Normal	20·00	41·00	22·00	38·90
A2	Overheated	22·10	45·90	14·00	19·60
A3	Restored	24·00	43·30	19·00	34·80
A4	Heated to 1100° C.	21·90	43·20	22·00	42·40

Tensile Tests.

In each case the test pieces were cut from the centre of the rail head.

Appearance of Tensile Fractures.

A1.—Fibrous.

A2.—Fracture was very largely crystalline, with no trace of fibrous structure.

The crystals were somewhat larger in the centre than on the outer portion of the test piece.

A3.—Fibrous; very fine, and having a silky appearance.

A4.—Fibrous; structure much finer than A1; very dull in appearance.

Series "B," "C," "D."

The section was the same for all series, viz.:—90 lbs. per yard bull head rail (North-Eastern Railway Section).

Manufacture.

Series "B."—Made from hæmatite iron on the basic open-hearth, and represents the normal composition for North-Eastern rail specifications.

Series "C."—Bessemer steel; was specially selected because of the high phosphorus present. It had been put to one side as unsuitable for making rails.

Series "D."—Made from hæmatite iron on the basic open-hearth; was specially selected on account of the high manganese.

Analyses.

	"B."	"C."	"D."
	Per Cent.	Per Cent.	Per Cent.
Carbon ...	0·45	0·36	0·46
Manganese ..	0·77	0·61	1·22
Silicon ...	0·04	0·02	0·02
Sulphur ...	0·054	0·075	0·05
Phosphorus ...	0·09	0·11	0·07

Each series comprised three rails, which were cut at the hot saw immediately after rolling, and were allowed to cool in air.

B1.—Normal rail as rolled; tested without further treatment.

B2.—Overheated at 1,300 degs. Cent. for 1½ hr., and allowed to cool down in air. This piece was divided into two parts when cold.

B3.—Part of B2 was again heated, and kept at a temperature of between 850 degs. and 900 degs. Cent. for 1 hr., and cooled down in air.

C1.—Normal rail as rolled; tested without further treatment.

C2.—Part of C1. Overheated at 1,200 degs. to 1,300 degs. Cent. for 1½ hr., and allowed to cool down in air. This piece was divided into two equal parts.

C3.—Part of C2 was again heated, and kept at a temperature of 850 degs. to 900 degs. Cent. for 2 hrs., and was cooled down in air.

D1.—Normal rail as rolled; tested without further treatment.

D2.—Part of D1. Overheated at 1,200 degs. Cent. for 1 hr., and cooled down in air; it was then divided as in previous series.

D3.—Part of D2 was again heated, and kept at a temperature of 850 degs. Cent. for 2 hrs., and cooled down in air.

Impact Tests.

All rails were allowed to cool down to ordinary temperature before testing.

Weight of ball ... 2,240 lbs.
Distance of drop ... 10 ft.
Bearings apart ... 3·5 ft.
Length of rail tested 5 ft.

Series No.	Treatment.	Deflection after 1st Blow. Inches.	Deflection after 2nd Blow. Inches.	Deflection after 3rd Blow. Inches.
B	B1. Normal ...	1¾	3¾	4 7/16
	B2. Overheated .	Broke	...	...
	B3. Restored ...	1¾	3 1/16	4¼
C	C1. Normal ...	1 11/16	3½	4 13/16
	C2. Overheated .	Broke	...	...
	C3. Restored ...	1⅞	3½	4 11/16
D	D1. Normal ...	1 15/16	2 15/16	3 1/16
	D2. Overheated .	1 15/16	Broke	...
	D3. Restored ...	1 15/16	2 15/16	3¾

Tensile Tests.

In each case the test pieces were cut from the centre of the rail head.

Appearance of Tensile Fractures.

B1.—Coarsely.
B2.—Entirely crystalline.
B3.—Fine; closely fibrous.
C1.—Coarsely fibrous.
C2.—Crystalline.
C3.—Fine silky fibre.
D1.—Finely granular.
D2.—Coarsely crystalline.
D3.—Finely granular, with indications of a tendency to fibrous structure in the centre of the test piece.

Series "A."—We must observe that series "A" was the first rail on which we experimented with a view to restoration, but, judging from the structure of the fracture, it was evident that the heating had not been sufficiently elevated. The results of testing also confirm that view. The pyrometer in this case most probably had not been correctly interpreted. In the following trials the results are most satisfactory, for in the "B" series the restored rail showed an increase in tensile strength of 0·7 ton per square inch, an increase in elongation of 9·5 per cent., and an increase in the contraction of area of 7·1 per cent.

The "C" series showed a decrease in tensile strength of 1 ton per square inch, with an increase in elongation of 1 per cent., and an increase in contraction of area of 1·6 per cent.

In the "D" series the tensile strength remained the same, but the restored rail showed an increase in elongation of 5 per cent., and an increase in contraction of area of 11·9 per cent.

Series "C."—This experiment was made from a cast in stock which had an unsuitable analysis for specifications; but we thought it would be interesting to take a rail ingot from this, containing, as it did, sulphur 0·075 per cent. and phosphorus 0·11 per cent., and subject it to the same treatment and tests as the others. It will be noted that, although the carbon is much lower than in the rails of the "A" and "B" series, the tensile strength in the normal rail is only a little below the others; but the elongation is considerably better than either, and the contraction of area is equal to that of the "A" series, and is 8·1 per cent. better than that of the "B" series, although the phosphorus is above the specified limit. The steel is proved by the mechanical tests to be excellent material in every respect.

Series No.	Treatment.	Yield Point. Tons per Square Inch.	Ultimate Stress. Tons per Square Inch.	Elongation per Cent. in 4 Inches.	Contraction of Area per Cent.	Average Hardness No. Brinell's Method. Ball 10 mm. Diameter. Load 5,000 kilos.	Average Hardness No. Brinell's Method. Ball 10 mm. Diameter. Load 50,000 kilos.
B1	Normal	20·40	40·10	18·50	29·50	150	148
B2	Overheated	32·40	39·40	14·75	15·50	147	142
B3	Restored	24·40	40·80	28·00	36 60	153	156
C1	Normal	19·35	38·10	25·00	37·60	133	149
C2	Overheated	20·30	37·40	21·00	20·70	132	144
C3	Restored	20·60	37 10	26·00	39·20	150	160
D1	Normal	28·10	50·80	11 00	12·50	210	209
D2	Overheated	26·90	50·10	7·00	6·00	190	191
D3	Restored	30·00	50·80	16 00	24·40	218	209

Experiments on 5-inch Blooms.

As the experiments with rails were so successful, another series of trials was made on a much larger mass of steel. A long steel bloom, 5 ins. square, was cut into 5 ft. lengths. One piece was tested in its normal condition without any treatment; two pieces were heated for four hours to a temperature approaching 1,400 degs. Cent., and were then taken from the furnace and allowed to cool on

the mill floor. One of these pieces was tested without further treatment. The second or duplicate overheated piece was reheated again to about 850 degs. Cent. for two hours; it was then removed from the furnace, and allowed to cool in the air. The results are appended below:—

Analysis.

Carbon ...	...	0·38 per cent.
Manganese	...	0·81 ,,
Silicon ...	...	0·04 ,,
Sulphur ...	...	0·062 ,,
Phosphorus	...	0 06 ,,

Impact Test.

Weight of ball = 2,240 lbs.
Distance of drop = 30 ft.
Bearings apart = 3·5 ft.
Length of billet tested = 5 ft.

Series No.	Treatment.	Deflection after 1st blow. Inches.	Deflection after 2nd blow. Inches.	Deflection after 3rd blow. Inches.
E1	Normal	2½	3¾	5¼
E2	Overheated	Broke	...	...
E3	Restored	1¾	3 5/16	5 1/16

Tensile Test.

In each case the test piece was cut from the central portion of the billet.

Series No.	Treatment.	Yield Point. Tons per Square Inch.	Ultimate Stress. Tons per Square Inch.	Elongation per Cent. in 4 Inches.	Contraction of Area per Cent.	Average Hardness No. Brinell's Method. Ball 10 mm. diam. Load 5,000 kilos.	Average Hardness No. Brinell's Method. Ball 10 mm. diam. Load 30,000 kilos.
E1	Normal ...	26·20	42·10	24·00	45·80	159	144
E2	Overheated .	26·80	42·80	12·00	13·40	151	133
E3	Restored ...	30·20	42·30	25·00	30·00	159	148

Appearance of Tensile Fractures.

E1.—Coarsely granular.
E2.—Entirely crystalline.
E3.—Finely granular.

Specific Gravity.

Series No.	Treatment.	Specific Gravity.
E1	Normal	7·8576
E2	Overheated	7·8458
E2	Restored	7·8567

Resistance to Repeated Alternations of Stress.

Professor Ewing and Mr. J. C. W. Humfrey, B.A.,* in one of the most valuable papers ever published on fracture of metals, have shown that iron, on being subjected to long continued alternation of stresses, becomes weak and eventually fractures in consequence of slipping along the cleavage planes of the crystals. In discussing their results they say: "It is remarkable that these actions, *i.e.* cleavage slipping, are brought about by stresses much below what is ordinarily understood by the elastic limit of the material. A tensile test shows proportionality of strain to stress up to 12 or 13 tons per sq. in., with no apparent defect of elasticity. The conditions under which these experiments were made seem to exclude the possibility that vibration gives rise to local augmentation of the stresses. The manner in which the slip-lines appear shows that some crystals reach the limit of elasticity sooner than others. This is no doubt to be ascribed in part to their being so oriented that the gliding planes, on which slip occurs, are inclined in the direction which is most favourable to the action of tangential stress. But besides this, it may be conjectured that in a complex structure built up of many crystals irregular in form, the distribution of stress from crystal to crystal is by no means homogeneous."

These hypotheses appear to us to be reasonable, and explain what actually occurs in the continuously stressed metal;

* "Fracture of Metals under Repeated Alternations of Stress," by J. A. Ewing, LL.D., F.R.S., and J. C. W. Humfrey, B.A., *Philosophical Transactions of the Royal Society of London*, Series A., vol. cc., pp. 241-250 (plates 7-9).

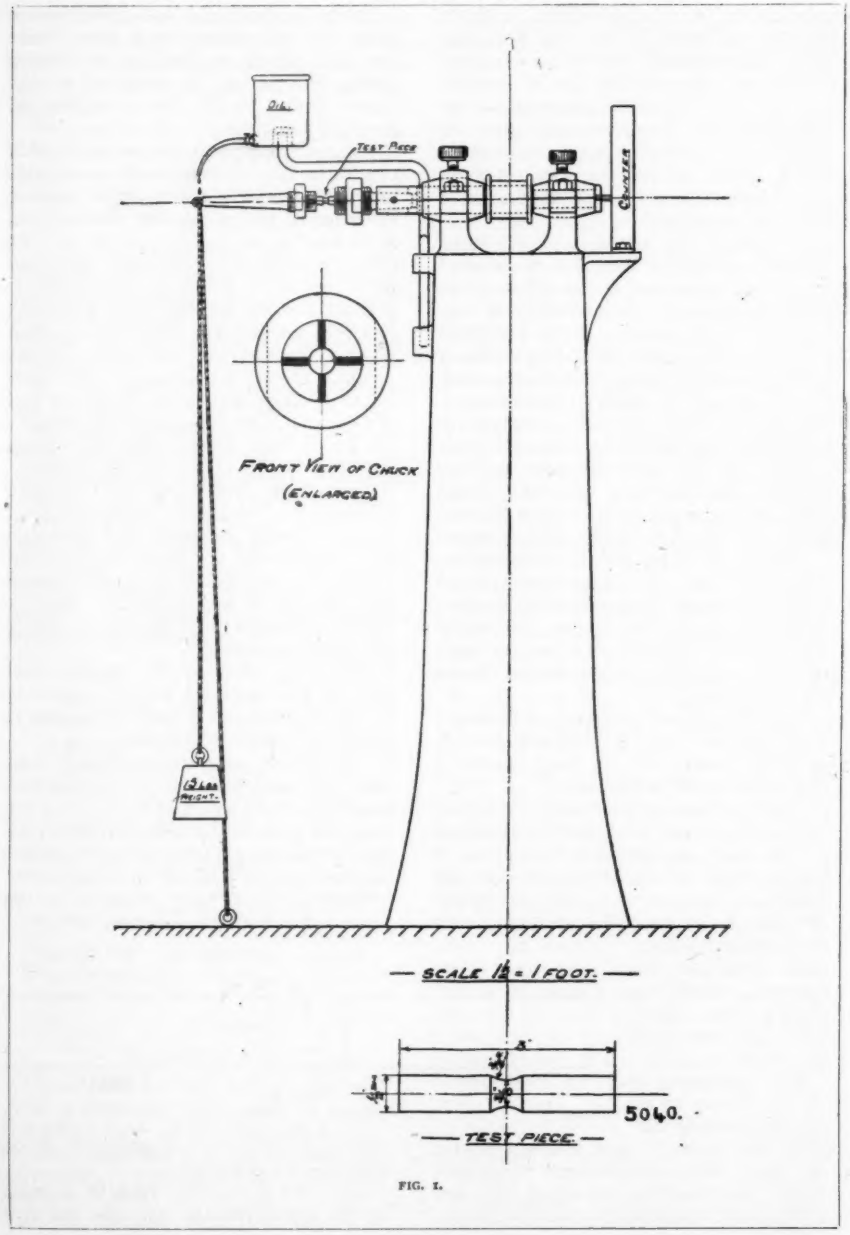

Oil.
Test Piece
Counter
Front View of Chuck
(Enlarged)
Scale 1/2 = 1 Foot.
5040.
Test Piece.

FIG. 1.

indeed, one of us, after careful study of the effect of strain on iron and steel, had quite independently arrived at a similar conclusion. In seeking for a suitable method to determine the resistance of the metals we were experimenting upon, we studied the several systems advocated which claim to indicate this property. The following is a description of a few of the most important :—

1st. One which was first employed by Wohler in which the bars of metal, secured in a chuck at one end and weighted at the other, are revolved continuously until they break or do not break. It was a method of this type which was adopted by Professor Ewing and Mr. Humfrey in their researches.

2nd. A method, similar in principle to the last, in which the bars, supported at both ends, are loaded at a central point midway between the supports, and are revolved till fracture is effected. A machine of this type is used in the Government Testing Works in the United States.

3rd. In which the metal is subjected to continued tensional shocks, insufficient to cause permanent elongation till it breaks.

4th. A system of testing in which notched bars, supported at one or both ends, are subjected to percussive shocks till they break.

5th. The method proposed by Professor Heyn and modified by Professor Arnold, in which small bars are bent backward and forward till they break.

Heyn, in testing practically pure iron, employed notched bars, and bent them to a right angle, straightened, bent again to a right angle and again straightened, and continued the process till the bars broke. Arnold, on the other hand, in testing ordinary structural steel, used small bars unnotched, which are slightly bent backward and forward till they break.

The process of testing metals by alternate straining has long been in use in steel and wire works, and some wire manufacturers claim that by the hand-bending test alone they can satisfactorily determine the quality of wire.

In the systems 1, 2, and 3 the bars of metal are not stressed to a point above the elastic limit, or what, by the tension system of testing, is accepted as the elastic limit. In all the others they are materially distorted.

Although it is premature to say whether or not the distortion methods are capable of yielding results which would indicate the value of the metals for practical use, it seemed to us that as metals are not distorted excepting accidentally when usefully applied, it would be inadvisable to depend on such methods until it is found that they give similar indications to those given by systems described under 1, 2, and 3, which are much more calculated to give what is equivalent to working stresses. We decided, therefore, to test our samples by the Wohler system, applying stresses below or slightly above the elastic limit.

Mr. Tom Westgarth (of Messrs. Richardsons, Westgarth & Co., Middlesbrough) kindly prepared and placed at our disposal the necessary machine and appliances, and in addition greatly assisted our research by machining the metal to shape and appointing one of his staff to attend to the testing.

The illustration of the machine (see Fig. 1) was prepared for this paper by Mr. Westgarth, and is sufficiently clear to require very little description.

Instead of using comparatively long bars, we have found it very convenient to employ short pieces of steel 3 or 4 ins. long and $\frac{1}{2}$ in. in diameter, in the centre part of which a groove is turned to reduce the diameter to $\frac{3}{8}$ in., or to 1 centimetre.

The size and exact shape of a test piece is given in the following sketch :—

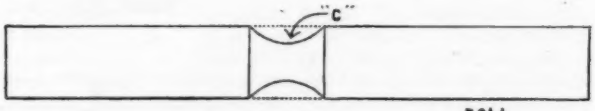


Fig 2.

The groove "C" is polished till all scratches are removed.

One end is securely fixed in a chuck on the wheel spindle. To the other an

extension bar or continuation piece is also fixed in the manner shown in the sketch.

The weight having been slung over the end of the extension portion the machine is started.

The speed of working, as registered by the counter, was about 2,000 revs. per min.

Swedish Iron.

Brand—Little's.

A bar $\frac{5}{8}$ in. in diameter was placed in a liquid mass of hæmatite blast-furnace slag weighing about four tons, and was allowed to cool down with the slag. When cold the slag ball was broken up and the bar removed.

By this treatment, in which the iron was heated out of contact air to about 1,300 degs. Cent. and was cooled very slowly during a period of three days, it was made most dangerously crystalline. One portion of it was tested in its brittle condition. A second portion was tested after simply reheating to a yellow heat and allowing to cool on a metal plate. The original bar was also tested, with the following results. The analysis of each portion was practically identical:—

	Per Cent.
Carbon	0·045
Manganese	0·085
Silica	0·056
Sulphur	0·003
Phosphorus	0·013
Oxygen	0·050

Resistance to Vibratory Stresses.

	Number of Reversals of equal Stress, 19 tons per square in. required to Produce Fracture.	
	1st Test	2nd Test
Original bar ...	50,710	51,170
Slag annealed ...	19,980	22,200
Restored by heating	541,040	...

Micro-Structure.

The original bar was variable, and consisted of large and small grains of ferrite. The grains were all very large in the slag annealed material, and the carbide had segregated. Pearlite was practically absent.

In the restored metal, the crystals of iron were much smaller than in the brittle material, but were most irregular in form.

Specific Gravity.

Original bar	7·7827
After slag annealing ...	7·8424
After reheating ...	7·8420

The remarkable result obtained with the Swedish bar, indicating as it does an enormous improvement, by being first made as brittle as cast-iron and then reheated, requires explanation. The original bar is not, we believe, designed for structural material, but is regularly used for melting in crucibles. It contained small plates of cinder cutting up the mass into sections, and in all probability the heat given to it originally at the works where it was made was not sufficiently strong to perfectly weld the particles of iron together. The effect of the very strong heating in the slag ball caused the enclosed cinder to melt and to behave exactly as do irregular shaped drops of oil when thrown into alcohol; they assumed the globular form, and were found in the cold metal as minute spherical masses. The metal itself had become perfectly homogeneous and continuous in structure, resembling that of pure melted iron, with the difference that the former contained the isolated globules of cinder, whilst in the latter there is none.

Soft Basic Steel.

This sample was kindly supplied by Mr. Arthur Cooper, and was made by the firm of which he is managing director. It was one on which Mr. C. H. Ridsdale had previously experimented and described in a paper read before this Institute in 1898. It consisted of a bar 2 ins. square which had been made brittle by long continued heating at high temperature. One portion was reheated to 950 degs. Cent., and was allowed to cool in air. A second portion was reheated and was forged down to a $1\frac{1}{2}$-in. square bar.

Chemical Analysis.

	Per Cent.
Carbon	0.05
Silicon	Nil
Phosphorus	0·055
Manganese	0·360

Resistance to Vibratory Stresses.

	Number of Reversals of equal Stress, 19 tons per sq. in. required to Produce Fracture.
Brittle Bar	14,947
Restored by reheating	158,143
Reheated and hammered	153,315

Micro-Structure.

In the brittle bar the crystals were variable in size, but on the average were very large.

The structure was much finer in the restored metal, and was still finer in that which had been hammered.

It would not appear, therefore, that the finest structure is necessarily the best in pure iron to resist vibration stresses.

Rails Series "C" and "D."

Resistance to Vibratory Stresses.

	Reversals of Equal Stress of 19 Tons per Square Inch.		Specific Gravity.	
	C	D	C	D
Normal ...	4,400,000*	1,671,440	...	..
Overheated	372,000	376,600	...	...
Restored ...	4,500,000*	5,654,870*	...	...

The specimens marked * at the time the proof of this paper was corrected had not been broken.

The system of testing requires much time, as will be understood when it is known that to obtain reversals of about six millions the machine has to run for eight hours during six days.

The results indicate in "D" series that, the steel having been made dangerously brittle, is by reheating not only restored but made at least three times as enduring as it was in the normal rolled state, and at least fifteen times as enduring as it was in the brittle state.

In "C" series the tests are not completed, but they show that by reheating the brittle material it is made at least twelve times as enduring as it is in its brittle state.

It was hoped that many more vibratory tests would have been ready for insertion in the paper presented to the members, but for reasons given above it has been found to be impossible.

The results, however, all point in one direction, viz., that dangerously crystalline and brittle steel can be changed to very high class material, possessing great power of resisting vibratory stresses, by simply heating to between 850 degs. and 900 degs. Cent., and without the necessity of forging to a smaller size.

The results of vibrating, etc., heated and forged basic steel would lead to the conclusion that forging embrittled steel is not advantageous, but we hesitate before making any more tests to state that such is always the case.

We know for a fact that wrought iron containing above 0·2 per cent. phosphorus, after embrittling, is not fully restored by reheating only. It is necessary to forge as well as to heat in order to remove the brittleness.

Conclusions.

In reviewing our work we believe that the following facts have been firmly established :—

1. The microscope in each experimental series indicates the same result, that heating at high temperatures causes a great development in the size of the crystalline grains, and reheating to about 870 degs. restores the original or a better structure.

2. If all structural steels in their normal rolled or forged condition are good, they can be readily deteriorated in quality by heating to a temperature a little above that to which steel is most commonly heated previous to rolling or forging.

3. Steel made brittle by such heating and dangerously brittle by heating at considerably higher temperatures can be completely restored to the best possible condition without forging down to a smaller size or by remelting.

Practically all our results show that not only are the original good qualities of normally rolled steel, after making brittle, restored by the exceedingly simple treatment of heating to about 900 degs. Cent. for a very short time, but that such steel is made considerably better than it was.

It is scarcely necessary to say how important and far reaching to steel workers and engineers this most valuable knowledge is.

That brittle "soft steel" can be restored by reheating has been proved by one of us, and confirmed by Professor Heyn, Mr. Ridsdale, and is well-known in Sweden, but that carbon steels can be actually made much superior to the original properly forged metal by reheating to 870 degs. and cooling in air is revealed at this meeting for the first time. It will be remembered that one of us at the Düsseldorf meeting last year urged upon those whom it might concern the imperative necessity of reheating to 900 degs. Cent. all forgings, and allowing them to cool in the air to remove accidental brittleness. The results given in this paper fully justify the statements then made. We would further urge that in every large forge and smith's shop Le Chatelier pyrometers should be introduced and in addition suitable furnaces for reheating the forgings, and that these should be systematically made use of.

From our own somewhat extensive experience we know for a fact that in many works steel is forged, rolled, and finished at temperatures far above what is the best for the endurance of the steel when put into practical use, and we feel confident that if such appliances were to be intelligently employed the finished forgings would be greatly improved. It must be acknowledged that it has been upon the inferior enduring properties of such material that engineers have had to base their factors of safety, with the inevitable consequence that on the average much greater margins have been allowed than would be necessary if the steel were invariably obtained in its maximum condition of strength and safety.

We are sanguine enough to believe that, as research advances, that enviable goal will ultimately be reached.

The work presented is certainly a movement in that direction, but we hope that by treating steel so as to obtain in it a large proportion of sorbite, still nearer shall we be to the highest aim of the metallurgist of iron and steel. We aim at making material which will be twice or three times as enduring as that commonly made to-day, and we believe that we shall be able eventually to make it.

4. We are convinced that the system often specified by engineers that forgings when being annealed shall not be heated to a temperature high enough to cause a scale, is wrong; 870 degs. Cent. is coincident with a blue scale, and the steel is improved by heating till it forms this scale.

5. When the forgings are of unequal section they may be heated to 850 degs. Cent. to 900 degs. Cent., and be then cooled in air, be oil-quenched, or be treated by any other Sorbyising process till they are a barely visible red, and finally annealed in a furnace at a dull red heat to remove the stresses produced by rapid cooling.

As indicating what work is being done in this direction in France we need only refer to a communication made by Mr H. Le Chatelier to the International Association for Testing Materials in 1901, in which he quotes the experience of Mr. Barba.

That gentleman, who experimented on soft steel by subjecting it in the form of notched bars before and after heat treatment to the falling weight test, obtained the following strictly comparative results:—

	Height of Fall of Weight to Produce Fracture.
Natural or annealed below 900° C.	0·40 m.
Annealed at 900° C. or above	2·00 ,,
Quenched above 900° C. and annealed below 700° C. ...	6·00 ,,
Quenched without annealing at 800°	1·40 ,,
Quenched without annealing at 840°	2·20 ,,
Quenched without annealing at 950°	4·47 ,,
Quenched without annealing at 1150°	5·00 ,,

After noting what can be done in improving steel by proper heat treatment, is it possible for any iron and steel metallurgists to continue to move in the old ruts?

We beg to acknowledge the invaluable assistance given by Mr. David Evans, Mr. Tom Westgarth, Mr. Edward Cook, Mr. R. C. V. Whitfield, and our assistants, to all of whom we accord our most sincere thanks.

J. E. STEAD, F.R.S.

ARTHUR W. RICHARDS.

NOTES ON LOCOMOTIVE AND RAILWAY ENGINEERING.

New Great Central Route to London.

THE concluding note in last month's issue it will be remembered, contained a promise that this subject should be dealt with in the succeeding number at greater length than was then found possible. In fulfilment of that promise the matter is now presented together with illustrations, and will give an idea of the character of the Works in the London district, and the stage of advancement which has been reached at the time of writing.

Strictly speaking, the Neasden-Northolt contract commences,—not at Neasden sidings as is generally supposed—but immediately West of the river Brent, distant some 8 chains from the Company's extensive goods-train marshalling ground at the former place, and about three-quarters-of-a-mile beyond the Kingsbury-Neasden station of the Metropolitan Railway.

The first bridge on the new line is that which spans the river in question, and shortly after passing this point the railway is in cutting at Wembley for a distance of 1 mile 3 chains. The retaining walls used through a portion of this distance, viz., that between Wembley Hill Road and Blind Lane are formed of concrete backing faced with brindle bricks, the height varying from 5 to 17 ft. on the South side and 10 to 31 ft. on the North side of the cutting, work on the latter being well in hand at the present time.

The walls are battered 1 in 8, the slope above them being trimmed 3 to 1. Pockets, at intervals of every chain, have been put in at the top of the wall, and are provided with four-inch pipes for draining off water.

Sufficient ground for four lines of way has been secured by the Company, but it is not proposed to furnish more than two at first. At Wembley Hill Road the second bridge is met with, and at the North End of the cutting a third is provided for carrying Blind Lane over the railway. Both are composed of girders and jack arches. The line, after leaving the cutting, is carried upon an embankment for a distance of 7 chains, until it reaches a public road bridge of girders and steel flooring, the span in this case being 40 ft.

Immediately after crossing this bridge, the new railway passes over the London and North-Western main line, north of that Company's station known as Sudbury and Wembley by a steel-lattice girder bridge. The photograph shows the girders in course of erection before being lowered into position on their bearings, and the London and North-Western Company's permanent way is clearly seen passing beneath the structure. The skew span of this bridge is 107 ft. in length, and the square span 99 ft., the main girders being 15 ft. in depth. Pneumatic riveting was employed on this bridge by the builders, Messrs. Butler & Co., of Stanningley Ironworks, Leeds, who are the sub-contractors for the whole of the steel-work on this contract.

The "rocker" or expansion ends of the main girders, shown in the illustration, are at the west or Northolt end, whilst the fixed ends are at the east or Neasden extremity. After clearing the London and North-Western Railway, and still proceeding in a westerly direction, the line is continued in bank for a distance of 70 chains, crossing a projected new road at 2½ chains by a skew-arch bridge of 40 ft. square span, and the new Harrowdene Road at 19 chains by a girder bridge of 60 ft. span.

At 36 chains beyond the last-mentioned bridge the main Harrow Road is crossed over, a bridge having a skew span of 72 ft. and square span of 65 ft. being provided for the purpose.

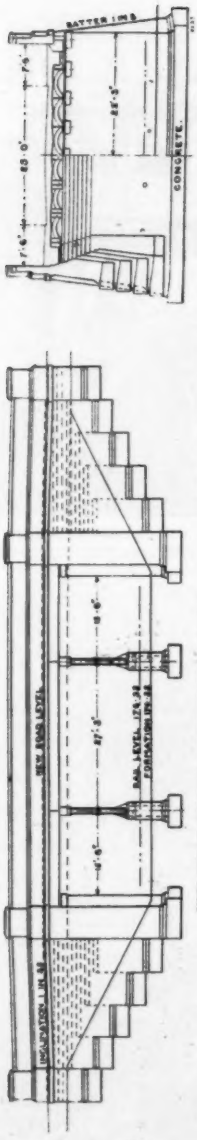
At this point a site has been tipped for a station, which, when completed, will be appropriately named Harrow Road, the first station after leaving Marylebone. The line now enters a cutting 64 chains long, and the next public road to be encountered is that of Greenford Lane, which at present is very little used for vehicular traffic. About half-a-mile further west the line passes under the public road leading from Greenford to Harrow. This road has to be raised 4ft. 6ins., and a double girder and jack arch bridge erected for carrying it over the line.

A station will also be situated at this point, to be known as South Harrow. After cross-

NEW GREAT CENTRAL ROUTE TO LONDON: BRIDGE OVER THE L. AND N. W. RAILWAY IN COURSE OF CONSTRUCTION.

NEW GREAT CENTRAL ROUTE TO LONDON: COVERED WAY.

Section of wall in the trench with a small piece of inverted arch at its foot. The semicircular timber dam in which the lengths of the arch are built has just been released and is ready to be drawn forward on which to build another length of arching.



NEW GREAT CENTRAL ROUTE TO LONDON: GREENFORD ROAD BRIDGE—GIRDER AND JACK ARCH TYPE.

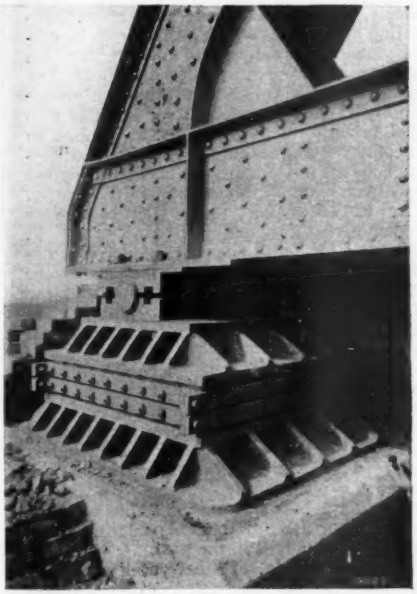
ing a small bank of about one chain in length, the line enters the third cutting, which is about one mile long. About 13 chains from the east end of this cutting a public road is carried across by a three-arch bridge, the centre span of which is 56 ft. and the two side spans 50 ft. each. About 21 chains farther on the line passes under the Ealing and South Harrow Electric Railway. For about 8 chains before this is reached the line is in cut and cover construction, consisting of a brick arch the span of which is wide enough for two lines of way. The abutments are of cement concrete faced with brindles, and the arch and invert of brickwork. The construction immediately beneath the Ealing and South Harrow Railway formation is of girders and jack arches, the total length of the covered way being about 600 ft.

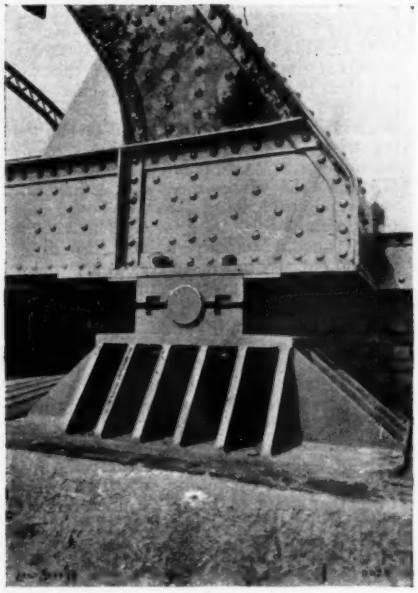
After leaving the cutting previously mentioned, the up-line is carried on bank until the junction at Northolt is reached. Two public roads are crossed—viz. the Harrow to Northolt Road—at about 10 chains after leaving the cutting, and the Ruislip to Northolt Road, about 55 chains farther west. Just before this latter point is reached the two lines (up and down) diverge, the former curving gently away to the right and the latter bearing to the left, with a falling gradient of 1 in 62, so as to burrow under the Great Western new line, after clearing which it rises 1 in 153 to the Junction. A considerable amount of "spoil" has been tipped both east and west of the river Brent, and some of the banks on the lengths have been prepared for four roads.

The soil is London clay throughout. A quantity is being burned and will be placed on the embankments to form a basis or foundation for the other permanent-way ballasting material. All cuttings under 15 ft. deep have their slopes trimmed at 2 to 1; those between 15 ft. and 25 ft. 2½ to 1 whilst all above 25 ft. are 3 to 1.

Pneumatic riveting is being employed on the steel-work of all the bridges. Work has been considerably retarded by the heavy rains experienced during the present season; rendering the soil in an exceedingly sodden and difficult condition for working. It is not anticipated that the combined undertakings will be completed before the end of 1904 at earliest, so that it will be some time yet before Mr. Robinson's fine engines are speeding their way North via the new route.

Once all is in working order, however, we may look for some greatly improved services on the Great Central Railway. The Metropolitan Company's obstructive tactics will then be a thing of the past and the antiquated methods of that concern as practised on the





G. C. R. BRIDGE OVER THE L. AND N. W. MAIN LINE.

ROLLER END OF MAIN GIRDER SHOWING THE ROCKER BEARING.

THE FIXED END OF MAIN GIRDER.

Aylesbury extension will no longer exercise any influence over the go-ahead policy of the "modern trunk line," a circumstance which the patrons of the latter will have much to congratulate themselves upon.

The photos from which the illustrations were prepared are the work of Mr. G. A. M. Baker, A.M.Inst.C.E., assistant to Mr. A. W. H. Casson, M.Inst.C.E., the Resident Engineer of the two new lengths of railway. In a later issue, it is proposed to give a description of the other portions of the route.

London to Sheffield without a stop.

Commencing with July 1st of the present year, the Great Central authorities put on a new vestibuled corridor express known as the "Sheffield Special," timed to cover the distance of 164¾ mls. in 3 hrs. 8 mins. without any intermediate stop. A corresponding up-train, allowed 2 mins. more in which to complete the journey, is also provided. Thus, although the Great Central route is longer than that possessed by either of the competing lines, the quickest way of making the trip between the Metropolis and the famous cutlery centre is by means of the trains which start from and arrive at Marylebone terminus.

By the courtesy of Mr. J. G. Robinson, M.Inst.C.E., Chief Mechanical Engineer of the Great Central Railway, the writer was recently afforded an opportunity of travelling upon the engine of the down train leaving London at 3.25 p.m. and due at Sheffield at 6.33 p.m., and every facility was provided for noting what transpired. The locomotive employed was No. 1041, one of the large four-coupled bogie engines of Mr. Robinson's design with Belpaire boiler, inside cylinders 19 ins. by 26 ins., and coupled-wheels 6 ft. 9 ins. diam. The engines of this class are fitted with Davies and Metcalfe's exhaust steam injectors, and they also carry a 9 mm. Gresham and Craven's ordinary pattern injector, so that an interesting comparison of the relative merits in working of the two types was added to the other useful information obtained. On the present occasion it will not be possible to give more than an outline description of the performance of the engine, but at a later stage it is hoped to

present further and more detailed particulars together with illustrations and diagrams.

As regards the running it may be said at once that the engine performed all that was required of it with the utmost ease, and, judging from all appearances, had a very large margin of power in reserve throughout the trip. The steam pressure was evenly maintained at close upon blowing-off point (180 lbs.) the whole way, and it was only very rarely that the regulator was open more than from 1½ in. to 2 ins. The vacuum gauge-needle steadily pointed to 21 ins. throughout. The most vexatious delays occurred whilst traversing the Metropolitan Railway system from Harrow to Aylesbury; but fortunately no actual stop occurred, although on several occasions speed had to be reduced to almost walking pace owing to adverse signals. The severe **S**-curve at Aylesbury, followed by the slack to 15 miles per hour at Quainton Road, combined with the frequent checks occasioned by the Metropolitan trains, resulted in a loss of 5 mins. before clearing Quainton Road. The 59 miles from that point to Leicester, however, were covered in 57 mins., so that the slipping operation at the latter place was performed at the advertised time—viz. 5.22 p.m. The run thence to Nottingham was accomplished at an even rate of speed; and, but for a stop by signal outside Sheffield Station, the arrival there would have been absolutely punctual. As matters stood it was 30 secs. late. There can be no doubt whatever that Engine No. 1041 and others of similar design are among the finest and most efficient of any locomotives in the country. The writer was particularly impressed by the spaciousness and comfort of the cab arrangement. Ample protection from weather conditions is combined with great accessibility of fittings in these engines. Although the design of the cabs of locomotives may be held by some to be a relatively unimportant point, there is little doubt that the duties of enginemen are rendered easier of accomplishment and the welfare of all concerned contributed to by the provision of a conveniently arranged "foot-plate," as in the present case.

A word of praise is due to the driver, Thos. Ogden, of Gorton, a man of many years experience, for his skilful handling of the engine.

Other observations on locomotives of the same class have also been made by the writer; these will be dealt with in a future issue.

Superheated Steam for Locomotives.

The difficulties attending the use of superheated steam with locomotives are being surely, if slowly, overcome, and the compensating advantages which accrue from its employment are brought into fuller recognition as the more serious drawbacks disappear. The name of Wilhelm Schmidt stands out prominently in this connection, for he it is who has brought the superheater as applied to locomotive engines into practical and advantageous use in Germany. Very little progress has been made in this country in the matter. One or two of the "1400" class of express locomotives designed by Mr. J. A. F. Aspinall for the Lancashire and Yorkshire Railway, are fitted with the necessary apparatus for superheating steam, and the majority, if not all, of the 20 odd engines comprising the series have steam-jacketed cylinders.

The amount of space occupied by the superheater is probably the greatest obstacle to its more general adoption nowadays. The serious difficulties which formerly attended the operations of lubricating the cylinders and packing the stuffing boxes have been almost if not entirely overcome by the use of mineral in place of vegetable oils and metallic or asbestos packing instead of the material employed in the past.

The vegetable oils then used were not adapted to resist high temperatures, and they decomposed at 400 degs. Fahr.; whereas the mineral oils now employed, with flash points above 700 and 800 degs. Fahr., allow of the use of steam superheated to 600 degs. without difficulty.

Experiments conducted by Lentz on locomotives fitted with the Schmidt superheater showed that, with low degrees of superheating to 450 or 500 degs., a saving of 15 to 20 per cent. in cost of working is effected. Saturated steam of 200 lbs. pressure has a temperature of 387 degs. Fahr. If it loses 175 lbs. its pressure becomes zero lb., but if steam of 200 lbs. is superheated to 600 degs. and loses 175 degs, its pressure remains at 200 lbs., and 38 degs. of superheat also remains. If however it loses these 38 degs. of superheat as well, the steam becomes plainly saturated, and any further loss of temperature is accompanied by condensation and loss of pressure.

In view of the successful results obtained in Germany with superheated steam locomotives, it would appear that the matter might be resuscitated here with advantage.

American Locomotives in England.

It will be remembered that a few years ago some of the British railway companies imported a number of American-built goods-engines. The Midland was the largest customer, and the chairman, Sir Ernest

Paget, speaking at a half-yearly meeting held in 1899, stated that the company required more locomotives, that they must have them quickly, and that they had decided to ask for tenders from American builders. As a result they obtained a promise of delivery of ten locomotives in ten weeks from receipt of order and twenty within four months from the same date. The earliest which any of the British manufacturers of locomotives could undertake to supply the engines was fifteen months ahead; consequently the order went to the States. It is said that the directors have had ample cause to regret the fact. The locomotives were delivered punctually, it is true, at a price commonly reported to have been less by £400 per engine than that quoted by any British firm. There, if all accounts are true, the advantages ceased. Before six months of service had been completed stories were in circulation to the effect that the imported engines were consuming from 20 per cent. to 25 per cent. more fuel and 50 per cent. more oil than their English contemporaries performing the same work; whilst, at a later stage, it was given out that they were costing 60 per cent. more for repairs than the home-built machines.

Quite recently similar reports respecting these engines are to hand, and from what is stated it appears that it has been necessary to carry out several alterations upon them so that they may be worked more economically. It is easy to lapse into hypercriticism when dealing with matters of this kind. The writer has no desire to cast any reflection upon American workmanship or methods of construction; and full allowance must be made for the conditions under which the orders were carried out. True, the recent "Canadian Pacific" contract—a subject already dealt with in these notes—presented difficulties to the English builders in an equal if not greater ratio than those which had to be overcome by the Americans in 1899-1900; but that is not so much the point. The most regrettable part of the whole business is that the orders were ever allowed to go abroad at all. The reason given—viz. that the home manufacturers were too full up with work at the time to undertake fresh contracts with assurance of delivery in the time required—was satisfactory enough so far as it went; but, if we examine the trade returns of a year or so previous to the dates of the contracts being given out, we find that the locomotive industry had experienced a very slack time, so that it would seem that the fault really lay with the railway authorities, whose short-sightedness resulted in valuable trade going out of the country. Surely it behoves all those who are in any way responsible for the arrangement of such important matters to look ahead and take the necessary steps to keep their stock numerically up to the standard of requirements, and by so doing help to prevent capital much needed at home from going abroad.

Railway "Records" and the Press.

A correspondent writes enclosing a lengthy cutting from one of the London daily papers, and requests that the matter contained therein may be commented upon in these notes, being in some doubts as to the accuracy of the statements which appear.

The column or so of matter sent purports to be a description of a "record" run on one of the principal British railways, but the most cursory glance through it should have sufficed to convince the sender of the untrustworthy character of the "information" published in the article. The matter is only referred to at this point, so that it may be understood in future that such reports as that received cannot be noticed in these columns.

Information of a technical character relating to Locomotive and Railway subjects vouched for on competent authority, or given as the observations of qualified persons, will at all times be gladly received and acknowledged. In cases where locomotive performances of exceptional merit have taken place, it is usually possible to obtain accounts of what did actually occur in the columns of one or other of the recognised engineering journals, so that there is no necessity whatever for anyone desiring information to have recourse to the unreliable and often totally misleading reports of non-professional writers in the lay Press.

Another correspondent sends an extract from one of the leading and most important technical journals, occupying the foremost position among the purely railway engineering publications. The present writer's attention is called to the remarks which appear in the extract, criticising certain statements made by a contemporary writer, who, in dealing elsewhere with the subject of locomotive boilers and a recent development of English practice in that connection, conveys an impression which is wholly opposed to the actual facts. Whilst agreeing entirely with the tone of the criticisms, and recognising to the full the legitimacy of their purpose, it is not considered desirable that such matter should be forwarded for discussion in these notes, and readers are requested to kindly make a note of the fact.

Rivet Spacing in Merchant Vessels Classed at Lloyd's.

THE intention of the writer is to classify the spacing of rivets according to the best practice, rather than to enter into a discussion as to the absolute correctness of that spacing, either from a practical or a theoretical point of view. Indeed, the practical consideration of making the structure water-tight, making joints suitable for the caulking tool, etc., precludes the spacing of any particular size of rivet, in any particular situation, varying, except within comparatively narrow limits.

The only really debatable ground is as to whether the size of rivets for each thickness of plate, as fixed by Lloyd's, is the best possible. It is highly probable that it would be found better to slightly increase the diameter of rivets in very thin plates where they have to stand any heavy water-pressure. Of course a calculation would show that the joint was somewhat weakened; but when the increased holding or gripping power of the rivet, and the superiority of the rivet itself, are taken into account, the loss is more apparent than real.

The subject is certainly worth consideration. Finding that the great majority of shipbuilding firms have no exhaustive list of rivet spacing, the writer has attempted to reduce the general practice of the best firms into a compact standard list, which is given in the following pages.

Any chief or leading draughtsman who has to co ordinate the work of his staff will at once recognise the usefulness of such a list; and most draughtsmen would be glad to have a reference more direct and complete than Lloyd's rules and regulations, which only indicate in outline what is required, and do not profess to completely cover the ground.

Mackrow's or Molesworth's pocket-books would be even more valuable than they are at present if they held a similar list within their covers. Shipyard managers and foremen platers, especially the latter, would welcome a handy reference, which, being in the hands of each plater, would take the routine work of checking the spacing of rivet-holes off their shoulders, and leave them so much more time for the performance of their more important duties. The platers themselves would be benefited, insomuch as they would be able to mark off the holes, even in work to which they were unaccustomed, without having to refer to their foreman for the correct rivet-spacing in every case of doubt.

When a plan comes into the plater's hands he usually finds that the riveting is specified so many DIAS. apart. He is not concerned with the number of diameters, but the number of INCHES. The proposed standard-list given below meets this requirement by giving the spacing both in terms of diameters and inches. Some firms, it is true, have compiled a list, more or less complete, but even then it is not always easily accessible to many of those who would most benefit by it.

An examination of the practice in all shipbuilding yards would reveal the fact that there is not a very great variation between them, probably because those cases which are left entirely to the experience of their employees approximate more and more closely, owing to the constant interchange of these employees, as men go from one firm to another to fill vacancies. All the more reason for having a fixed standard which will be of equal use to all.

It would be a simple matter to have a riveting list framed, and hung in every drawing-office and mould-loft, and it might perhaps be printed in the shape of a pamphlet, a copy of which could be given to each plater. If that be considered too expensive—which is unlikely

in our cheap printing days—it might be copied on to tracing paper, and blue prints struck off to any required extent. In cases where a framed list for drawing-office or mould-loft use is decided upon, the list might be supplemented by sketches of many minor details, such as diamond and semi-diamond plates, beam arms, distance centre to centre between rows of reeled rivets, etc. These sketches have been omitted in the following list, in order to keep it as concise as possible.

Riveting List for Vessels Classed at Lloyd's.

Position of Rivets.	Spacing in Diameters.	Diameter of Rivet.				
		½in.	⅝in.	¾in.	⅞in.	1in.
		Pitch of Rivet in Inches.				
Frames to reverse frames	7					
,, floor plates	7					
,, frame brackets (reeled) ...	7	3½	4½	5¼	6¼	7
,, shell plating	7					
,, stringer knees	7					
Beam arms to frames	6" beams	... FOUR ¾" rivets			—	—
,, ,, ...	7" to 8½"	beams, FIVE ¾" ,,			—	—
,, ,, ...	9" to 9½"	,, FIVE ⅞" ,,			—	—
,, ,, ...	10" to 10½"	,, SIX ⅞" ,,			—	—
,, ,, ...	11" to 12"	,, SEVEN ⅞" ,,			—	—
Where beam knees are THREE times the depth of beam, are to have ONE additional rivet.						
Beam angles to beams	7					
,, knees to web frames	7					
Reverse frames to floor plates	7	3½	4½	5¼	6¼	7
,, ,, web frames	7					
,, ,, tank brackets	7					
Web frames to frame (reeled)	7					
,, butts (lapped)	4½ to 5	2¾ to 2½	2⅞ to 3⅛	3¼ to 3⅜	3⅝ to 4⅜	4½ to 5
Bulkhead seams	4 to 4½	2 to 2¼	2½ to 2⅞	3 to 3⅜	3½ to 3⅞	4 to 4½
,, butts	4	2	2½	3	3½	4
,, vertical stiffeners	7 to 8	3½ to 4	4⅜ to 5	5¼ to 6	6⅛ to 7	7 to 8
,, horizontal stiffeners	7 to 8					
,, W.T. upper-deck angles to deck	4 to 5	2 to 2½	2½ to 3⅛	3 to 3¾	3½ to 4⅜	4 to 5
,, non-W.T. ,, ,, ...	7	3½	4⅜	5¼	6⅛	7
,, ,, main ,, ,, ...	7					
,, W.T. ,, ,, ,, ...	4 to 5					
,, main deck angle to bulkhead ...	4 to 5	2 to 2½	2½ to 3⅛	3 to 3¾	3½ to 4⅜	4 to 5
,, upper ,, ,, ...	4 to 5					
,, non-W.T. frame to shell ...	7	3½	4⅜	5¼	6⅛	7
,, W.T. frame to shell	4½ to 5	2¾ to 2½	2⅞ to 3⅛	3⅜ to 3¾	3⅞ to 4⅜	4½ to 5
,, frames to bulkhead	4½ to 5					
,, tank top angles to bulkhead ...	4 to 5	2 to 2½	2½ to 3⅛	3 to 3¾	3½ to 4⅜	4 to 5
,, W.T. tank top angle to tank ...	4 to 5					
,, non-W.T. ,, ,, ...	7	3½	4⅜	5¼	6⅛	7
,, vert.-stiffened knees to tank top	6	3	3⅜	4½	5¼	6
,, horizontal ,, ,, shell ...	6					
Central keelson bottom angles to keel ...	5	2½	3⅛	3¾	4⅜	5
,, ,, ,, keelson.	5					
,, ,, top angles to tank top	7					
,, ,, ,, keelson.	7	3½	4½	5¼	6¼	7
,, ,, vert. angles to floors.	7					
,, ,, ,, keelson.	7					
,, ,, butts of plating ...	4	2	2½	3	3½	4
Intercostals :—						
Angles connecting ditto to floors ...	7	3½	4⅜	5¼	6⅛	7
Angles connecting ditto to tank ...	Frame spacing 23" or above 4 rivets per space.					
,, ,, ,, ,, shell ...	,, under 23" —3 ,, ,,					

Position of Rivets.	Spacing in Diameters.	Diameter of Rivet.				
		½in.	⅝in.	¾in.	⅞in.	1in.
		Pitch of Rivet in Inches.				
Intercostals *(continued)*:						
Angles connecting floors to margin plate and Angles connecting frame brackets to margin plate.	Margin plate 20″ to 22″ deep			FIVE ⅜″ rivets.		
	,, 24″ to 26″ ,,			SIX ⅜″ ,,		
	,, 28″ ,,			SEVEN ⅜″ ,,		
	,, 30″ to 32″ ,,			SEVEN ½″ ,,		
	,, 35″ to 38″ ,,			EIGHT ½″ ,,		
	,, 40″ to 42″ ,,			NINE ½″ ,,		
	,, 44″ to 46″ ,,			TEN ½″ ,,		
Tank side angle to margin plate	4½ to 5	2½ to 2½	2⅞ to 3⅛	3⅜ to 3⅝	3⅞ to 4⅛	4½ to 5
,, ,, shell	4½ to 5					
W.T. tank division frames (both flanges)	4½ to 5					
Tank top plating (seams)	4	2	2½	3	3½	4
,, ,, (butts)	4					
Hold stringer, face angle to stringer ...	7 to 8	3½ to 4	4⅜ to 5	5¼ to 6	6⅛ to 7	7 to 8
,, frame ,, ,, ...	7 to 8					
,, ,, ,, reverse bar ...	One rivet.					
,, shell bar to shell	4 rivets in each space if 23″ or above.					
,, ,, ,, stringer ...	4 ,, ,, under 23″					
,, lugs to web frames ...	4 to 5	2 to 2½	2½ to 3⅛	3 to 3¼	3½ to 4⅜	4 to 5
Stringers of deck plating to beams ...	7 to 8	3½ to 4	4⅜ to 5	5¼ to 6	6⅛ to 7	—
Stringer plate butts on upper, spar or middle deck		3½	1⅜	2¼	2⅝	3½
Stringer plate butts on poop, bridge or forecastle		4	2	2¼	3	3½
Seams of all deck plating	4 to 4½	2 to 2¼	2½ to 2⅞	3 to 3⅜	3½ to 3⅝	—
Butts ,, ,, ...		4	2	2½	3	3½
Gunwale stringer angle in each flange ...		4½	2¼	2⅝	3⅜	3⅞
Deck stringer, shell pieces to shell ...			(see hold	stringer	shell bar)	
,, frame angle to stringer ...	7 to 8	3½ to 4	4⅜ to 5	5¼ to 6	6⅛ to 7	—
,, frame angle to stringer in way of gutter waterway or wood deck	5	2½	3¼	3⅜	4⅜	—
Deck stringer, frame angle to reverse ...				One rivet.		
Deck stringer waterway bar	5	2½	3⅛	3⅜	4⅜	—
Shell plating seams...	4 to 4½	2 to 2¼	2½ to 2⅞	3 to 3⅜	3½ to 4	4 to 4½
,, butts	3½	1¾	2¼	2⅝	3⅛	3½
Bunker plating seams or butts	6½ to 7					
,, corner angles	6½ to 7	3½ to 3½	4 1⁄16 to 4⅛	4⅝ to 5¼	—	—
,, foundation angles... ...	6½ to 7					
,, vertical stiffeners	9 to 10	4½ to 5	5⅜ to 6¼	6⅜ to 7⅛	—	—
,, foundation bar to tank top	4½ to 5	2¼ to 2½	2⅝ to 3⅛	3⅜ to 3⅝	—	—
,, deck bar to bunker or deck	6½ to 7	3½ to 3¾	4 1⁄16 to 4⅜	4⅞ to 5¼	—	—
Screen bulkhead seams or butts	8 to 9	4 to 4½	5 to 5⅜	6 to 6¾	—	—
,, vertical stiffeners	10	5	6¼	7⅛	—	—
Tunnel plating seams or butts	4½ to 5					
,, foundation angles ...	4½ to 5	2⅜ to 2½	2⅞ to 3⅛	3⅜ to 3⅝	3⅞ to 4⅛	—
,, vertical stiffeners	8	4	5	6	7	—
Tunnel stools	5	2½	3⅛	3¾	4⅜	—
Bilge keel angles to shell	4½ to 5					
Belting and rubbing angles to shell ...	4½ to 5	2½ to 2½	2⅞ to 3¼	3⅜ to 3½	3⅞ to 4⅛	4½ to 5
Bilge keel angles to bulb	8	4	5	6	7	8
Cargo hatch foundation angles	4½ to 5	2½ to 2½	2⅞ to 3¼	3⅜ to 3½	3⅞ to 4⅛	4½ to 5
,, butts	6 to 7	3 to 3⅜	3½ to 4⅛	4½ to 5¼	5¼ to 6⅛	—
,, top bar	8	4	5	6	7	—
Bunker hatches, similar to cargo ditto ...	—	—	—	—	—	—
Poop, Bridge and Forecastle fronts or ends (also deckhouses) as follows :—						
Foundation bars (in each flange) ...	4½ to 5	2½ to 2½	2⅞ to 3¼	3⅜ to 3⅝	—	—
Coaming seams or butts	5 to 6	2½ to 3	3¼ to 3⅝	3⅝ to 4½	—	—
Vertical or horizontal seams, either lapped or pilastered...	8	4	5	6	—	—
Vertical stiffeners	9	4½	5⅛	6¾	—	—

Position of Rivets.	Spacing in Diameters.	Diameter of Rivet. ½in.	⅝in.	¾in.	⅞in.	1in.
		Pitch of Rivet in Inches.				
Engine and Boiler casings as follows :						
Foundation bars where exposed ...	4½ to 5	2¼ to 2½	2⅝ to 3⅛	3⅜ to 3¾	—	—
,, ,, under cover	5 to 6	2½ to 3	3⅛ to 3¾	3¾ to 4½	—	—
Coaming seams or butts	5 to 6					
Seams and butts of plating	8	4	5	6	—	—
Vertical stiffness on laps	8	4	5	6	—	—
,, ,, flush butts ...	8					
Vertical stiffeners	9 to 10	4½ to 5	5⅝ to 6¼	6¾ to 7½	—	—
Casing divisional bulkhead seams ...	8 to 9	4 to 4½	5 to 5⅝	6 to 6¾	—	—
,, ,, stiffeners	10	5	6¼	7½	—	—
Mast seams or butts	5	2½	3⅛	3¾	4⅜	5
Back row of treble-riveted strap butts (unless strap is caulked)	5 to 5¼	2½ to 2⅝	3⅛ to 3 5/16	3¾ to 3 15/16	4⅜ to 4⅝	5 to 5¼
Stem and stern posts and keel bars ...	5	—	—	—	4⅜	5
Treble-riveted LAP butts	To have 3 complete rows of rivets				—	—
Quadruple	,, 4		,,	,,	—	—
Butts of frame angles, keelson angles and stringer angles	To have not less than 3 rivets on each side of butt					
Butts of reverse bars (unless butted at centre line)	To have 2 rivets on each side of butt					—
Lugs on reverse bar to take keelsons or hold stringers	Connected to frame by 3 rivets				—	—
Thickness of Plate (inclusive)	—	3/20 to 4/20	5/20 to 6/20	7/20 to 8/20	10/20 to 13/20	14/20 to 18/20
Corresponding diameter of rivet	—	½	⅝	¾	⅞	1
Breadth of quadruple-riveted strap ...	—	—	—	19	22	25
,, treble- ,, ...	—	—	12	14¼	16¾	19
,, double- ,, ...	—	—	8	9½	11¼	—
,, quadruple-riveted lap	—	—	8	9½	11¼	13
,, treble- ,, ...	—	—	6	7½	9	10½
,, double- ,, ...	—	—	4¼	5	6	—
,, double-riveted seams	—	—	3½	4½	5¼	6
,, single- ,, ...	—	—	2¼	2½	—	—
Number of rivets in each row of outside plating AMIDSHIPS :						
20" frame spacing	—	—	—	7	5	—	—
21" ,, ...	—	—	—	7	6	5	—
22" ,, ...	—	—	—	—	6	5	—
23" ,, ...	—	—	—	—	6	5	5
24" ,, ...	—	—	—	—	7	6	5
25" ,, ...	—	—	—	—	—	6	5
26" ,, ...	—	—	—	—	—	6	5

Size of Countersink for Rivets in Shell Plating.

Diameter of rivet.	Diameter of hole at faying surface.	Diameter of hole at top.
½"	11/16"	1"
⅝"	13/16"	1 1/16"
¾"	15/16"	1 3/16"
⅞"	1 1/16"	1 5/16"
1"	1 3/16"	1 7/16"
1 ⅛"	1 5/16"	1 9/16"

All countersinks to extend right through plate.

No bosom pieces are fitted to cargo or bunker-hatch foundation bars, engine and boiler casing foundation bars, poop, bridge and forecastle fronts or ends, deck-house foundation bars, etc.

Wherever a lap of plate on to an angle, or two angles to each other, exceeds 2½ ins. to 3½ ins.—according to size of rivet—the holes are to be reeled.

No rivet holes are to be punched in frames at turn of bilge until the frames are turned.

Pillars 10 ft. in length and under 18 ft., and from 2⅞ ins. to 4 ins. in diam. to have:—Two ⅞-in. rivets in head and heel. Ditto, 18 ft. to 24 ft. long and above 4 ins. diam. to have:—Two 1-in. rivets in head and heel. Ditto, over 24 ft. long to have:—Three 1-in. rivets in head and heel.

Where channel beams are fitted on alternate frames in lieu of tee bulbs, the rivets in the flange to deck to be spaced only 5 diameters apart.

Rivet holes round boundary of diamond-shaped bulkhead liners to be spaced 4½ to 5 diameters apart.

Clear space between each row of rivets in butts = Twice diameter of rivet. Ditto in seams = One-and-a-half diameter of rivet.

No rivet to be nearer the edge of any plate or angle than its own diameter.

Where the fore and aft flange of the frame angle does not exceed 3 ins., the rivets attaching the shell plating thereto should not exceed ⅞ in. in diam., and when it is 3½ ins. wide, they should not exceed 1 in. in diam.

In all cases the thicker of the two plates or angles is to regulate the size of the rivets.

C. C.

Entropy: a New Text-Book.

When the present year opened a controversy which had begun a short time previously, and was destined to disturb the usually calm atmosphere of the physical and engineering community of this country, was reaching its height. Mr. Swinburne, in his presidential address to the Institution of Electrical Engineers, had ventured to call in question the accuracy of text-book writers in their definitions of the "ghostly quantity," entropy; and Professor Perry had rushed into the fray to defend himself and other writers. The storm which then ensued has long since died away (cf., however, abstract of recent article by J. Swinburne in "Engineering Abstracts" section), and no one desires to see it renewed, at least in its old form. Our readers will remember that at the time we summarised the discussion, and reviewed the opinions of the principal persons engaged in it.* But such a controversy is not without effect. It was evident from the great interest taken in the discussion, and from the editorial comments in numerous journals, that Mr. Swinburne had performed a useful service in raising the question; and although the subject no longer appears in the correspondence columns of the technical papers, one feels that the attitude of the scientific public towards it has been changed. One result of the controversy is that we must adopt a more critical attitude in considering the treatment of entropy in any new books on thermodynamics or physics; and as one book of the former class, published in America in the present year, is now before us, we propose to discuss briefly the author's remarks on entropy in the light of the information provided by the Swinburne-Perry symposium.

This work† is by Mr. Sidney A. Reeve, Professor of Steam-engineering at the Worcester Polytechnic Institute, U.S.A., and is devoted to a discussion of the theoretical principles of thermodynamics and of their application in practice in the simple and the compound steam-engine and in the Otto gas-engine. As we desire to deal here only with the entropy question, we need only say of the rest of the book that both in matter and in manner it is very good, and reveals the author as a writer of considerable originality, and having the power of expressing clearly and in an interesting fashion what he desires to teach. We are not aware of the actual date of publication of this work, but it seems fairly clear that it was written before any question had arisen of the correctness of the method usually followed by thermodynamicians in discussing entropy. The author concerns himself solely with reversible cycles, and the fault with which Mr. Swinburne charged the text-book writers, of not making this limitation and its consequences as clear to readers as is possible, appears at a very early stage. He begins by treating heat as a form of energy, having as its two dimensions temperature and entropy, in the same way as mechanical energy of the potential type has two dimensions, height and weight; and this analogy is brought repeatedly before the reader. By it he arrives at the "fundamental equation of all thermodynamic calculation"—

$$d\phi = \frac{d\mathrm{H}}{\theta},$$

where ϕ is entropy, H the quantity of heat involved in the change, and θ the absolute temperature at which the change occurs. He then gives a definition in general terms, as follows:—

> "Entropy is that quality of a body which increases when heat is added to the body, which decreases only when heat is abstracted, and consequently remains constant only when heat is neither added nor abstracted."

Leaving the mathematical definition alone for the present, we see that the

* Feilden's Magazine, March, 1903.
† "Thermodynamics of Heat Engines." The Macmillan Company: New York and London. 1903.

general definition is somewhat different from that usually found. Indeed, most writers avoid giving any but the mathematical definition. Here, however, an attempt has been made, and we have to consider the result. In the first place, there is nothing said here about a cycle, reversible or irreversible; and although the definition is given in the chapter dealing with "The Cycle," it appears in the early pages of that chapter, before the reader has been introduced to the cyclic process. We may, therefore, treat it as perfectly general; but is it adequate, and is it correct? It is true that if we add heat to a body its entropy increases, and that the body which gives up this heat in turn loses entropy; but neither of these statements leads us to a conception of what this "quality," called entropy, is. It is also true that if heat is neither added nor abstracted the entropy *may* remain constant; but it need not necessarily do so, for, as Mr. Swinburne has shown, the entropy can increase without the substance taking in any heat at all. Thus the definition, which seems to consider entropy as depending solely upon the transfer of heat as heat, is defective, if not actually incorrect. The error arises from the habit of considering thermal energy as the product of temperature and entropy, and tracing an analogy to potential mechanical energy. No doubt this analogy is attractive, and, when properly restricted, may be usefully applied; but it is apt to lead to error, and it obscures the real importance of entropy.

The author tabulates the different forms of energy, showing each as the product of two factors, classified generically as a "factor of extent" and a "factor of intensity." Thus in potential mechanical energy, the factor of extent is force, and distance is the factor of intensity; in kinetic energy, the factors are mass and velocity; in thermal energy, entropy and temperature. Of the two factors, the author points out that in all the other forms of energy than thermal energy, the factor of extent is always a function of *mass*, while the factor of intensity is always a function of velocity of motion, or of remoteness of separation of the mass involved. He then points out that entropy as a factor of extent—since it shows none of the characteristics distinguishing factors of intensity—"must be either mass itself, or else some close function of mass." It is clear that there are difficulties in following out this conception, and the author is not blind to them; but he holds fast to the original statement, and is thereby led, or rather forced, to a conclusion which is certainly interesting in view of modern developments in the study of molecular physics. We give the author's own words:

"It will develop upon the most superficial inspection of thermal phenomena that entropy is an active variable. If entropy be mass the inevitable deduction must be, since the mass of a body remains constant during heating or cooling, that the proportion of the mass of the body which takes part in thermal vibration must be variable. Since thermal energy is normally distributed evenly throughout the body containing it, this must mean that *there is a variable portion of the mass of each atom which enters into the motion which constitutes thermal energy*. This variable portion, according to the first hypothesis given above, is the entropy of the body. If not, it is at least an active factor in that entropy."

This ingenious hypothesis is supported by the author in a foot-note, in which he points out the changes which have been made in our conception of the atom by modern investigations. Our assumptions with regard to the atom, he says,

"have had to grow in complexity with the growth of knowledge until it is now accepted that what we attempt to define as an atom is merely a mass of matter very much smaller than human dimensions, but which, instead of being an indivisible, elementary sort of thing, may be, and is probably, as complex within itself as are the largest known masses of matter. So that it is quite feasible to suppose that varying portions of its mass may enter into those motions and positions which we lump under the title of thermal energy."

The hypothesis, according to the author, has neither been proved nor disproved, but he holds that,

"to the student who takes the trouble to study the real significance of thermodynamic phenomena this hypothesis that entropy is thermal mass, although not demonstrably exact, will be found to be a great and proper aid."

Now, in spite of the attractiveness of this speculation, it must be noticed that its basis is the conception of thermal energy as the product of entropy and tem-

perature, and Mr. Swinburne has asserted that such a conception is erroneous. He has strenuously insisted that entropy is not a factor of heat, especially in the following paragraph from his letter in the *Electrician*, of January 2, 1903.

"The writers I find fault with do not all make exactly the same mistakes. Many of them define entropy as the quantity factor of heat energy. Auerbach is a striking example. See also parts of Helm. In the cases of irreversible change I have mentioned, where the body increases in entropy at constant temperature, its internal energy remains constant though its entropy increases. The entropy cannot, therefore, be a factor of the energy. Again, let some perfect gas expand reversibly and isothermally, taking in heat H at temperature θ, and giving out energy equal to H to a mechanism. The entropy of the gas increases by $H/\theta=\phi$; but, as the temperature and energy of the gas are not altered, ϕ cannot be a factor of the increased energy of the gas. Where is the particular energy of which it is the factor? The reservoir has lost some energy which has been passed on by the gas to the mechanism, and the entropy of the intermediate link—the gas—has been increased at constant temperature; so entropy is not a factor of heat."

Here, then, we have a fundamental difference between the views of Mr. Swinburne and those of Mr. Reeve and other writers on thermodynamics. If Mr. Swinburne's view be correct, as we believe to be the case, since it is in accordance with the ideas of the founders of the science of thermodynamics, then the usefulness of the hypothesis put forward by Mr. Reeve must be seriously limited. An hypothesis may be erroneous and yet may be found useful in practice, and as thermodynamicians concern themselves only with reversible cycles—although they do not always make this clear—the consequences of the error are to some extent reduced. But the merit of Mr. Swinburne's view is that it reveals the importance of entropy in *real* changes. According to him, the criterion whether an action will take place or not is the answer we give to the question: "By that action will the entropy be increased or not?" If yea, the action will take place; if nay, it will not. If the entropy would be reduced, then the action is impossible; if it would remain the same, the system is in equilibrium, and the action will not take place. In chemical changes, as Mr. Swinburne has pointed out, this is the only test.

The entropy of the universe always tends to increase; but Mr. Reeve seems disposed to look upon this statement as requiring modification. He expresses the old law of dissipation of energy in the form:—"the entropy of the world tends to a maximum, and the temperature to a minimum," and he adds,

"The modern statement of both sides of the law, in similar language, would be: The total entropy and the average temperature of the universe remain constant. But no such law may probably be true, for entropy and temperature are respectively the mass and the intensity of only one sort of energy. Since there is as yet no evidence accumulated which reveals any fixity of proportion between the several sorts of energy in the universe, although in all probability that proportion is rigidly controlled by natural law, no law similar to the above may be stated which confines itself to a single form of energy, such as heat."

In this paragraph we see a difficulty which meets the author in consequence of his treating entropy as a factor of heat. He has previously laid down the law of conservation of matter in these words, "The mass of the universe ever remains constant in quantity." If entropy be mass, therefore, he must reject the Kelvin-Clausius dictum, "Entropy always increases," or must at least modify it to the form he has given above, but in that form it is unsatisfactory, as the average temperature of the universe must tend to a minimum. And if instead of the whole universe, we consider a simple thermally isolated body, or system of bodies, we must assert, as indeed the author does, that its entropy never alters in quantity, whereas Mr. Swinburne has shown that it is possible for its entropy to increase, and that it will increase if any action can take place within the system. The inter-diffusion of two mutually inert gases affords an example. Mr. Reeve says that when the thermally isolated body meets another and exchanges energy of like sort, "there appears no law of connection between the direction of the interchange and the degree of entropy present." That is a natural corollary to the proposition that the total entropy is constant, but it is incorrect; for the exchange of energy will take place, and can only take place, in the direction which leads to an increase in the total entropy.

In several other respects, the author's treatment of the subject is open to the criticism made by Mr. Swinburne against text-book writers generally. We have seen that he gives a definition of entropy at the outset by a mathematical equation, which leads to the usual integral,

$$\phi = \int \frac{d\,\mathrm{H}}{\theta},$$

and that integral only holds good in reversible changes. Then he treats adiabatics and isentropics as synonymous, and again this is only true in reversible changes.

"In the case of a perfect gas expanding wholly irreversibly into a vacuum, the change is both adiabatic and isothermal at the same time, but it is not isentropic."—Mr. SWINBURNE, *Electrician*, Jan. 2, 1903, p. 443.

We need not, however, dwell on these matters, as enough has been said to show that there is need for a complete revision of the text-book method of explaining entropy. Professor Reeve has followed older thermodynamicians, but not the oldest, the pioneers of the science; and as Professor Perry has admitted that all modern men use the term entropy in a different sense from that in which it was used by Clausius, who introduced it, we are entitled to ask by what right, or on what grounds the change has been made, and if it appears that something has been lost by the change, may we not further ask for a return to the old and original use of the term? If this were done, it would be necessary to show clearly the limitations put upon it in discussing the hypothetical reversible cycle, and this would be a clear gain. At present, the discussion of the special case, as if it were general, leads to ambiguity and error.

W. C. H.

TOPICS OF THE MONTH.

British Empire Trade.

IF we except the British Islands, India, and a few minor colonies, the British Empire is little more than a name. Supreme governing power is theoretically vested in the Sovereign and in Imperial Parliament, but virtually each of the self-governing colonies is almost as independent as the United States. The only bonds holding together these scattered units are to be found in affection for the Mother country, and in unswerving loyalty to the Throne. But what we proudly describe as "The British Empire" is not an empire at all, according to the old-time acceptation of the term. In these days of constitutional government, the Sovereign never dreams of exercising even his theoretical powers without the concurrence of Parliament, and similarly the theoretical powers of Parliament over the Colonies are never likely to be exercised without the previously-given assent of those dominions. If the attempt were so made, the consequence might be rupture as complete and as irrevocable as that which happened in the case of the colony that became the United States Republic.

As matters at present stand, the separate self-governing states of the Empire make welcome the bonds that hold them to the Mother country, but Imperial Parliament no longer occupies the authoritative position it once held. Whether it will ever be possible to constitute a Chamber including representatives from each state in the Empire and endowed with supreme powers for dealing with all Imperial affairs, is a question that the future alone can answer. In the absence of such a council, the only means of regulating what may perhaps be termed international affairs within the Empire is by friendly conference and mutual arrangement. By the interchange of ideas, as well as by judicious action for the realisation of schemes that are generally acceptable to the dominions and colonies themselves, much may be done towards laying a sure foundation for a genuine Empire, bound firmly together by ties of mutual interest, and, above all, by loyalty to a common Sovereign.

A few months ago we saw the first representative conference of Colonial Ministers, and more recently some eminently practical suggestions for the furtherance of British Empire trade have been foreshadowed by the Colonial Secretary. The proposals in question, although not clearly defined, have been warmly welcomed, in principle, in Dominions beyond the Seas, but in this country there are many who regard them with the utmost disfavour. If a real and a strong Empire is to be built up, we, in the Home Country, must be prepared to look at things by the light of the sun as it shines to-day, and not by the dim twilight that is reflected by tradition from the sun of a bygone generation.

At present we are the passive slaves of the Free Trade theory, and we have been taught to repeat, as if they were Divine revelations, the shibboleths invented many years ago by the originators of that doctrine. Since that period many things have happened.

The anticipated adoption of Free Trade by the world at large has not taken place, the conditions of trade and of foreign competition have altered, and our Colonial Possessions have become developed to an extent that was never thought possible by those who lived half a century ago. If Cobden and Bright could come back to us in the present day, it is quite conceivable that they would be

the first to join hands with those who believe in the formulation of a fiscal policy on rational lines for the benefit of the Empire. Every self-governing colony is protective, and every Englishman who has lived abroad for a few years comes back to his native land a confirmed Protectionist. It is only in England that Liberals and Conservatives are alike faithful to the once Radical doctrine called Free Trade. As a nation we think too little about the welfare of the Colonies, except in a purely theoretical sense, and too much about our own pockets. If the Imperial idea is ever to become a reality, we must adopt more enlarged views, and be ready to give as well as to take, in matters with which other States of the Empire are concerned.

We have shown in previous articles, how our simple-minded faith in Free Trade is being abused by American and German traders. Our manufacturers and workmen alike are suffering from the extensive depredations made upon our industries in the manner indicated, but we do nothing. Why? Apparently because a small band of gentlemen interested in the cotton trade said some fifty years ago that Free Trade would be a good thing if universally practised. As a truism this is excellent, but the affairs of a country, and especially of an Empire, cannot be governed by copybook maxims. The time has now come when practical views are an imperative necessity, and strong but wise action is equally essential.

We have not the slightest intention of suggesting the details of an Imperial Fiscal Policy. That is a matter requiring the most serious and earnest consideration of experts in statesmanship and finance. But we do urge that the country at large should be prepared to regard the whole question with an open eye, and to think it out with an open mind.

A balance must be struck between Great Britain and the Colonies. Those states are prepared to send us in ample abundance food-stuffs and raw materials of various kinds. If our demands should increase, there would be not the slightest difficulty in increasing supplies. Therefore it does not necessarily follow that a small duty upon foreign, but not upon Colonial, products would have the effect of raising prices, providing due notice were given, so that Colonial planters might prepare for increased production.

When we are prepared to offer advantages to the Colonies they, too, will be ready to make provision for the preferential treatment of our home industries, as Canada has already done; and as greater industrial prosperity means more money in the pockets of working men, it would matter little even if the cost of some necessaries were increased by a slight percentage. But we do not admit that such increase would inevitably follow the adoption of a revised fiscal policy.

We do not propose to refer at length to the advantages that would accrue to the country at large, and to working men in particular, if our industries were reasonably and moderately protected from unfair ravages due to foreign bounties, or equivalent encouragement to make this country a dumping-ground for foreign-made goods at less than cost price. We have already witnessed the ruin of the sugar, silk, and other industries, and many trades are now languishing because we retain a suicidal policy based upon ideals that are no longer applicable to the prevailing conditions under which we live. Here are clearly matters for wise statesmanship.

Turning now to inter-Imperial trade, let us look ahead towards the state into which we are rapidly drifting. Taking the case of Australia and New Zealand, we find that the import and export trade of these two States with Great Britain amounted, in 1901, to upwards of £64,000,000, being about a million and a quarter more than the trade with India, and more than double the trade with Canada during the same year. And beyond this the Australasian trade with other British possessions amounted to fully £15,000,000. In the same year, however, the trade of Australia with foreign countries represented more than £27,000,000, and this is a fact which we ought not to overlook. During the ten years, 1881-91, Australian trade with the Home Country increased by

£13,457,000, or very nearly 27 per cent.; but the same decade showed an augmentation of foreign trade by £8,650,000, or about 120 per cent. Between 1891 and 1901 Australian trade with Great Britain increased by the comparatively small amount of £3,150,000, less than 5 per cent.; while Australian foreign trade increased by £11,738,000, or 74 per cent.

Facts of this kind are not generally known, and even when they are known the obvious remedy does not always suggest itself. Such facts are striking symptons of a deadly disease which is gradually sapping the strength of the Empire. Yet, as a nation, we go on in the old way with cheerful optimism. Politicians are too busy with party strife to worry about important affairs like this. Manufacturers grumble, but do nothing. Workmen do not realise their import, and Trade Unions are too busy in other directions to enlighten their members.

The population of Australia is essentially British, and there is every disposition in the Commonwealth to favour British manufacturers in preference to foreigners. Yet the figures we have quoted suggest most forcibly that in a few years time, foreign trade will surpass in amount the trade done with the Mother country.

We have taken Australia as an example, but it does not stand alone. On every side both at home and abroad, we are threatened by the wide-a-wake and enterprising foreigner, who is diverting to his own country the orders that should find work in increasing abundance for British manufacturers and British workmen.

The obvious remedy is to be found in a wise and statesmanlike adjustment of customs duties, taking away from the foreigner the power of underselling us in our own markets, and in the establishment of reciprocal tariffs between the Home Country and other Dominions of the Empire, so that suitable encouragement may be given to Colonial produce on the one hand, and to British manufacturers on the other. But, as before said, we must be prepared to give up narrow, insular views, and to consider the whole question with a broad-minded appreciation of our Imperial responsibilities.

The Education of Engineers.

For some time back there has been something like a "boom" in education in this country. For years we had been jogging along comfortably, firmly persuaded that in education and intelligence we were easily first among the nations, and that there was little fear of our losing that proud position. But gradually, and at first timorously, voices were raised, uttering warnings that all was not well, as we fondly imagined, and that we were even living in a fool's paradise. These voices might have been disregarded, had they not been supported finally by our own Prince of Wales, who returned from his tour in the Colonies with the cry of "Wake up, England!" on his lips. *That* voice could not be disregarded, and John Bull awoke from his slumbers.

Now, if it be a difficult matter to awaken John Bull, there can be no doubt that, once he is roused, he makes plenty of noise in setting to work to find a remedy for the evil which has been brought to his notice, and in the case we are considering we have had excellent illustrations of this fact.

During the past two years speakers on platforms and writers in the press have seemed to take a delight in pointing out how ignorant our country is compared with others, how poorly educated are our engineers and manufacturers, and how far behind we are in providing proper facilities for technical and industrial education. There is no doubt much truth in what they have said, and as their outcry has led to schemes being devised for the better equipment of our technical schools and colleges it has been amply justified.

But in the discussion there have appeared also a great deal of exaggeration, a considerable amount of misplaced effort, and a good deal of nonsense. It is a curious fact that most men, while recog-

nising their limitations in other respects, consider themselves fully qualified to speak, and even to give advice, on the subject of education. Men who have no experience of schools or colleges, who know nothing of the immense amount of thought and skill devoted to their organisation, are ready at a moment's notice to criticise and condemn the systems they find in vogue, and to lay down the law as to what should be taught and how it should be taught. Naturally, the recent period of national introspection has given full opportunity to such men to air their views, but luckily the good sense of the nation has prevented the people from accepting these views at the value their authors put upon them.

An amusing feature of the situation is, that while our self-appointed experts are always telling us to study what is done in America, we find that in that country there is at the present time even a greater amount of discussion than here over the proper courses of study for different professions; and that while the real authorities in this country have made up their minds on what they want, and are discussing the best means of carrying out their object, the Americans still seem to have a fondness for the quest of the ideal curriculum.

We find an illustration of the position in each country by referring to two recent engineering congresses, one in London and one at Niagara Falls. At the engineering conference held in London in June by the Institution of Civil Engineers, the question of the education of engineers was discussed, but it was not thought necessary to spend any time on the consideration of the proper subjects to occupy a place in the curriculum. Practically all our engineers are now agreed on this point, as by experience the courses of study in engineering provided by our universities and colleges have been found to be well adapted for the purpose they are intended to serve. They may perhaps with advantage be extended, if the student can spare the extra time and money, but in themselves they give sound instruction in the principles of engineering, and send out graduates qualified to do their work intelligently in practice and able to profit rapidly by experience.

No doubt we could easily find a large number of men all ready to criticise and find fault with these courses of study, but these men do not count for much; and it is clear that when the representative engineers of the country arranged to meet to discuss education they were agreed that the theoretical studies might be left alone, but thought that a useful purpose might be served by discussing the best method of combining the theoretical studies with practical work in engineering shops. Hence came the interesting discussion on what is now known as the "sandwich system" of training—that is, the system under which young students spend six months of the year at college or university and the remaining six months in shops.

This system has to some extent been adopted in Scotland, more especially in Glasgow where several engineers and shipbuilders have shown their willingness to co-operate with the university by taking students into their shops and yards in the summer months. It will be readily seen that this system cannot succeed without hearty co-operation between employers and college authorities. However greatly the professors may desire to see it carried out, they must hope in vain unless employers are willing to take in these half-year apprentices, and in the past this willingness has not generally been too apparent. It is therefore very gratifying, on reading the reports of the discussion at the conference, and of that on the same subject at an earlier meeting of the Institution of Mechanical Engineers, to note the very hearty approval given to the system from many well-known and influential engineers. We believe that this method of training is the best possible, as the student has opportunities from the outset of applying the theoretical knowledge he has gained to practical problems. If he takes his practical training before he goes to college he finds the return to books and examinations a severe strain after being away from them for a few years. On the other hand, if he completes his theoretical training before going to the shops, he finds it difficult to be content

with only an apprentice's wage when he feels that he knows so much more than other men around him who are doing the same or even better work. But by combining the practical with the theoretical training, the advantages of each are more fully realised, and the student profits accordingly. We hope to see an extension of this system in the country as a result of the conference.

The discussion was full of interest and of great practical usefulness, as speakers were not dealing with abstract ideas or fancies but with the results of their own experience. If it were always so in educational discussions, much would be gained, but this is rather the exception than the rule. We have now to examine a discussion of another type.

America has done excellent work in recent years in the education of her sons, and she has reason to be proud of her educational institutions. In technical education she has many advantages over this country, and her wealthy sons seem to have vied with one another in providing fully equipped colleges and laboratories. Yet, with all this, we do not find that she is yet satisfied. Education, we have already said, is an attractive theme for most men, but it seems to have special charms for the American, and nowhere do we find more written and spoken on the subject than in America. Hence we find that there is in the United States a Society for the Promotion of Engineering Education, organised for the purpose of discussing problems relating to the education of engineers. It meets annually, and receives reports from special committees and papers from individual members. It has been in existence for some years now, and one might think that by this time it would have arrived at a definite decision on the course of study an engineer should follow, but, as we shall see, this is not the case. In July of this year, this society held a joint meeting with the American Institution of Electrical Engineers at Niagara Falls, the discussions being entirely devoted to the question of the education of electrical engineers. We cannot deal here with all the papers, but an idea of the general nature of the discussion may be gathered from the following titles of some of them :—

"The Problems that are facing the Electrical Engineer of To-day, and the Qualities of Mind and Character which are needed to meet them."

"The Proper Qualification of Electrical Engineering School Graduates, from the Telephone Engineer's Standpoint."

"The Proper Qualifications of Electrical Engineering School Graduates, from the Manufacturer's Standpoint," and

"Training an Artist in the Forces of Nature."

There is something very characteristic of modern tendencies in education in the second and third titles quoted above. Why should it be necessary or desirable to consider the proper qualifications (educational, be it remembered) of an electrical engineer from the special points of view of a telephone engineer and of a manufacturer? We know that there must be specialisation, but surely the special training should come as an addition to and not in substitution for a thorough and sound training in general engineering. The speaker, for example, who gave the manufacturer's point of view considers that in the technical schools the pupils ought to be taught (1) the principles of organisation, both of tools and staff, in workshops; (2) proper systems of works accounting; (3) the history of the relations between capital and labour and the economic laws relating thereto; and (4) the principles of the law of contracts.

Now we may readily admit that all such knowledge as is here sketched out is of great practical value; but is there to be nothing left to individual effort and to practical experience? Is it not a wholly false, though a very common, conception of the function of schools and colleges which seeks to make them turn out a completely finished product? Why should a boy or lad, at the most susceptible period of life, be expected to learn from books and lectures what he can learn afterwards with infinitely less pain when in actual contact with business life? The old notion of school-life, and even of university life—and one, be it remembered which produced the great engineers of the

past, who had no technical training at all in their young days—was that that was a period which ought to be devoted to the training and development of the mind, not to cramming it with facts on special subjects, but using studies as a means of training the scholar's mind to such a state that when he leaves school he will be able to use his intelligence, to think for himself, and rely upon himself: to observe things and remember them afterwards. Take a lad so trained by a purely general education and take another of equal intelligence who has spent some time of his school life at special subjects *at the expense of general education*, and let them both be set to practical work in one of these special subjects, and it will probably be found that although a superiority will be with the latter at the outset the other will soon overtake him, and as an all-round man this other will soon show his superiority.

It must not be thought, from what we have said, that we are against technical education. Nothing could be further from the truth. We desire to see our young engineers get as much technical training at school and college as they can find time for; but in face of the enormous amount of literature and eloquence which has been recently devoted to this subject, much of which has appeared to us to be dangerous nonsense, it seems desirable to enter a protest against the tendency to over-specialisation, and still more against specialisation at too early a period. These engineering conferences have supplied us with an opportunity. Let us not forget that it is not only now we are beginning to train engineers. We have done fairly well in that line in the past, and mere common-sense bids us stop to consider if a system which produced all that long line of engineers can have been so wholly bad, or hopelessly inadequate, as it is now painted. If our schools turn out trained and cultured minds, we shall not want for trained engineers. As was wisely remarked by Professor Carhart in the discussion in America, the object should be to make an engineer, not a specialist.

—•—

Mr. Andrew Carnegie's Presidential Address before the Iron and Steel Institute.

It is twenty-nine years since the Institute held its autumn meeting at Barrow. I have recently looked over the proceedings of that notable meeting. These seem to carry us back almost to the very beginning of cheap Bessemer steel manufacture in America, in which, as usual, Britain was the pioneer and taught the younger Republic. It was at that meeting your fellow-member and Bessemer Medallist, Alexander Lyman Holley, then our engineer from the Carnegie Steel Works, read the two papers which first brought to your attention the doings of your American brethren in developing the Bessemer process you had given them.

There are several here to-day who were then present. Such was the impression made upon the meeting that after the discussion, in proposing a vote of thanks, our Nestor, Sir Lowthian Bell, as President, said, "There was no doubt that in America they were doing great things in the manufacture of Bessemer steel, and their friends on the other side of the Atlantic were not averse to telling them what they did, and not only what they did, but how they did it. He thought, under the circumstances, if any member of that Institute was entitled to the thanks of the meeting it was the gentleman who had just read the last two papers."

The effect of these papers, as you know, is a matter of history. Mr. Josiah T. Smith, of Barrow, one of the greatest of your managers, and subsequently President of the Institute, characteristically said that Mr. Holley would find that, as far as Barrow was concerned, "They would try and do as well, in regard to quantity, as the United States," which struck the right note. There spoke the true Briton, who has done according to his means more than any other, the American not excepted. The record of the great little mother of nations is not equalled by any of her children, although her oldest and biggest seems to inherit his mother's indomitable spirit and the ability to work miracles. In all matters of iron and steel, however, the child has been borne upon the shoulders of the parent. If the Atlantic Ocean had been prairie land, there would have been little left in the world but the conquering old lady and her family, all under one roof, under one flag—a self-sustaining empire under free trade, with probably two hundred millions of our English-speaking race, and a home market so big as to give control of neutral markets. No question of protection or preferential tariffs then to disturb us; besides all this, we

should have been able to enforce peace among nations. It would have been a case of Britain *versus* all the rest of the world, the world kicking the beam.

Unfortunately an ocean exists where we should have preferred prairies, but it is traversed in about the same time as the three thousand miles of land between Montreal or New York on the Atlantic, and San Francisco and Victoria on the Pacific. Who so bold as to predict that never is our race to succeed in converting the ocean, hitherto a barrier to your extension, into the pathway to re-union of the two once united branches? Not I! My faith is unshakeable that some day this will be accomplished, and that, instead of being two small islands here, alien to the European Continent, you will look across the sea to your own children in Canada and the United States, and become once more the mother member of the dominant power of the world.

Mr. Whitwell participated in the discussion and asked Mr. Holley to give his opinion on the "from one-half to three-quarters more product which could be got from the converter in America than we were getting in England," which Mr. Holley answered after reading his second paper. It was chiefly owing to his own invention of bottoms in reserve and removable appliances.

There was also at this historical meeting a report, a remarkable production, submitted by David Forbes, Foreign Secretary to the Institute, upon the progress of iron and steel industries in foreign countries. I naturally turned to see what he had to say about the United States. Several pages are given to the Pittsburg district, and what is there recorded carries me back to the days of youth apparently. In 1873 the Pennsylvania Steel Company made 20,000 tons of steel rails. They make that amount in two weeks now. Bethlehem Iron Works were engaged in raising a loan of the enormous amount of £20,000 for the extension of their works, a paltry 100,000 dollars. Five millions would be comparatively less to-day. The great Cambria Iron Works in Western Pennsylvania, near Pittsburg, were credited with having made no less than 1,027½ tons of ingots in the week ending September 26th, the largest quantity ever made in a week—a day's work nowadays. Two new blast-furnaces were being built in Ohio, the capital of the company being all Scotch, and it was proposed to call the iron Scotch-American pig. This isn't a bad brand—either of men or iron. It is noted that the total production of pig iron in the United States in 1872 was 2,897,000 net tons, and in 1873 just about the same; to-day it is approaching 20,000,000 tons per annum. The product of steel, nearly 15,000,000 tons, is greater than the rest of the world.

The progress of Germany and Britain have also been great. Britain made 643,317 tons of steel in 1874, and last year 4,909,000 tons. Germany made 361,946 tons in 1874, last year 6,394,000 tons. In 1874 Britain made 6,054,000 tons of pig iron, Germany 1,906,000 tons. Last year they made 8,517,693 and 8,403,000 tons respectively. In 1874 the world was producing nearly 14,000,000 tons of pig iron and 280,000,000 tons of coal. Now there is being produced 41,000,000 tons of pig iron and 780,000,000 tons of coal.

Another item: Mr. Forbes is informed that for the last seven months natural gas has been utilised in Pittsburg in one of the mills. The largest output for a furnace then known was during the week ending September 7th, 1874—702½ tons; 100 tons per day. When our Lucy furnace made 100 tons in one day the world thought the limit was surely reached. Two new Carnegie furnaces have recently averaged 650 tons each per day for months at a time.

Records are given of various enterprises which promised brilliant results, but which are already things of the past. Perhaps the most noticeable point of all is that not the slightest mention is made of the Carnegie Steel Company—so much a thing of yesterday it is. It was making iron and building bridges, and had also furnaces in operation, which were visited by the late Thomas Whitwell; but it was scarcely worth noticing, as its steelworks were then only under construction. So rapidly do things grow in the new land!

You have noticed that the blast-furnace product increased more than six times, and also the rail-mill's product about the same. The work of a week is now done in a day; but great as is that contrast, here is one still greater. There have been made and sold without loss hundreds of thousands of tons of 4-in. steel billets at 3 lbs. for *a penny*. Surely the limit has been reached here! I think it has, and it is doubtful if ever a lower price can be reached for steel. On the contrary, there is every indication that period after period the price of steel is to become dearer, owing to the lack of raw materials. To make that 3 lbs. of steel at least 10 lbs. of material were required—3 lbs. of coke, mined and transported 60 miles to the works; 1½ lb. of lime, mined and transported 150 miles; and 4½ lbs. of ironstone, mined at Lake Superior, and transported 900 miles to Pittsburg, being transferred twice, once from cars into the ship, and again from the ship into the railway cars. How it was done I

cannot pretend to tell you, but I know the figures are correct. But every time I repeat them I doubt their possibility. This was done during the day of depression, when everything was at the lowest. Costs are several dollars per ton higher to-day during this period of boom in America.

Such is the contrast between 1874 and 1903. What is it to be twenty-nine years hence? What changes are to come? I have tried to imagine some of its features. It is scarcely possible that this country can increase its product of iron and steel materially. Let us hope that the product will not be decreased. The vital element in the matter is, as we all know, the supply of iron ore. Many of you are conversant with the situation here. I only know what I learn from others; but undoubtedly the attention of iron and steel manufacturers should be directed to this question—Where and how can they obtain a supply of iron ore?

Nor is it a question which the manufacturer of America can safely neglect. It was because it forced itself so strongly upon us that we secured such an abundant supply of the best ore obtainable. For sixty years, I think, the United States Steel Corporation is supplied at its present rate of consumption, but sixty years is as nothing in the life of a nation. It is upon future discoveries of iron ore that the future of cheap steel manufacture, even in America, depends. There are immense deposits in now inaccessible parts. In Utah, for instance, and in Southern California large deposits have been found; so that steel will continue to be manufactured, but it would not surprise me if its cost was very greatly advanced in the future. It seems almost miraculous that such an article as steel could be produced and sold without loss at 3 lbs. for *a penny*. I am convinced that this is a thing of the past. It will be a question of increased cost, and therefore of increased price, so that neither Britain nor America need fear that steel manufacture will be wholly lost; the world will gladly pay the increased price necessary to obtain it. During the next half century it seems that America is to increase her output at a tremendous pace. The output of Britain will perhaps remain stationary, or even increase somewhat, if developments in Norway and Sweden prove satisfactory.

Even if this Barrow meeting should fail to rank in importance historically with the first one, I am sure that in the warmth of welcome received, in the enjoyment of the occasion, and in the meeting of one with another, the records will not fail to show that 1903 compared favourably even with its epoch-making predecessor.

Some Recent Viaducts.

Truro Viaducts.

On the Cornish division of the Great Western Railway may still be seen some earlier and daring efforts in bridge and viaduct construction designed by Brunel to meet the exigencies of economy and strength. Some of these early viaducts were replaced by iron, steel and stone structures in his lifetime, although the work of reconstructing the remainder was not commenced until 1892, when the doubling of the line, which consisted only of a single track, was commenced.

Among these fast disappearing timber-and-composite structures, there are many well worthy of notice.

The viaduct which carried the Cornwall Railway across Truro was 1,365 ft. long and 92 ft. high. It had 21 spans each of 66 ft., and was constructed in 1852. The lower portions of the piers were of stone, and the upper of kyanised yellow pine, which on removal were found to be in an excellent state of preservation.

This structure has now given place to something of a more substantial character carried out in brickwork and masonry.

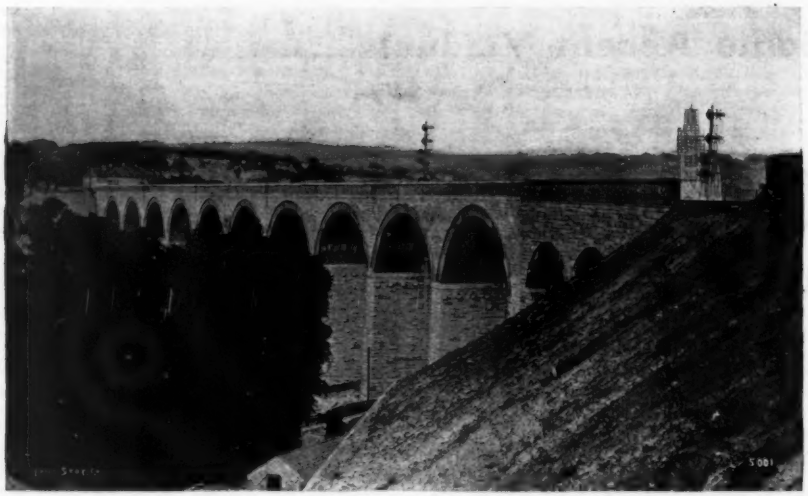
The principal dimensions are as follows. There are 18 spans each of 57 ft., with a rise of 23 ft. The piers, of which Nos. 6 and 12 are buttress piers, are 7 ft. 6 ins. in width at the top and are battered 1 in 48. Plinth course 40 ft. down (see side elevation) 13 ft. thick.

The piers are of granite throughout, as are also the abutments. Staffordshire brindles have been used for the arches, backed with local bricks from South Devon, the spandrils being faced with brindles and backed with cement concrete of a thickness of 3 ft. 6 ins. The central backing is composed of granite set in lime mortar, and solid backing of this description is carried up to a height of 15 ft. 6 ins. above the springing level. Above this smaller piers have been built running longitudinally with the viaduct, on which jack arches are turned. The crowns of the jack arches are level with the crowns of the main arches, which are 3 ft. below rail level. The whole is covered over with lime concrete up to within 2 ft. below rail level at side fleeting to the centre to permit of drainage.

The string courses are of granite, as is also the coping, the parapets being of brick.

The foundations are all in rock and

THE NEW TRURO VIADUCT NEARING COMPLETION.



CARVEDRAS VIADUCT.

the greatest height to rail level is 95 ft. The direction of the viaduct, which spans a valley, including a river and two occupation roads, is partly on the straight and partly on a curve. The total length of the viaduct is rather over a ¼-mile.

The Carvedras viaduct, some distance to the east of the Truro viaduct proper, calls for some notice. The principal dimensions, as well as the details of the specification, are practically similar to those of the Truro viaduct, with the exception of the spandrils, these having been built in granite throughout.

Operations were somewhat seriously interfered with owing to want of room at the western approach by reason of the old viaduct running alongside, thus preventing the completion of the last two arches by about 4 ft. 6 ins. until traffic was diverted over new viaduct and the old one demolished. At the eastern end, the proximity of the old viaduct prevented the wing being got up nearest it, so that the embankment could not be tipped to take one line of rail. Temporary girders were therefore thrown across from the bank, as far as it could be tipped, to cross girders fixed in the new viaduct. Traffic was then diverted over this improvised bridge and worked as a single line. This was done in August, 1902; the complete demolition of the old viaduct was taken in hand at once, the work being now completed.

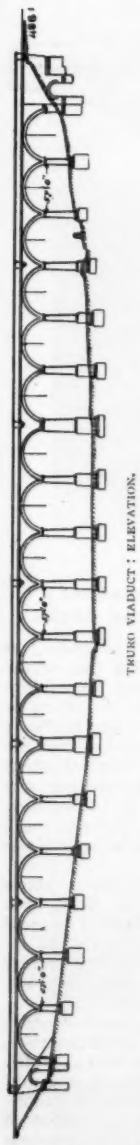
In addition to the work in connection with the construction of the Truro (proper) and the Carvedras viaducts, there was the widening of a bridge and the building of a retaining wall between the two.

The whole work was carried out by Messrs. Relfe & Son, contractors, from the designs of Mr. J. C Inglis, M.Inst.C.E., and under the supervision of Mr. Fox, to whom we are indebted for these details.

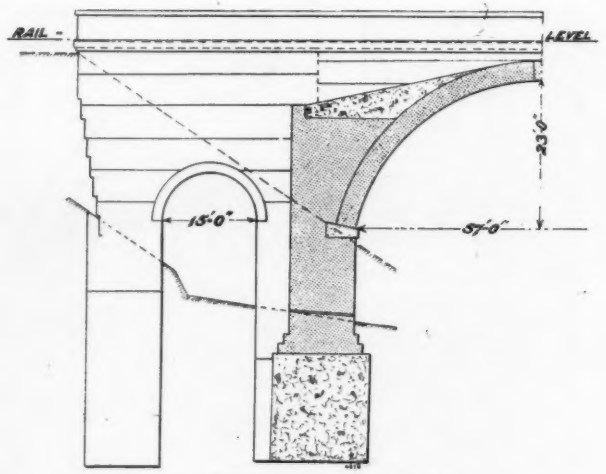
The Weston Mill Viaduct.

Although only 2½ miles in length, the doubling of the Great Western Railway Company's main line between Devonport and the Royal Albert Bridge at Saltash is of some engineering interest, as it has involved the reconstruction of a large viaduct over part of the estuary of the River Tamar, and known as Weston Mill or Camel's Head Lake, situated immediately north of the new station which has recently been provided at Keyham.

The old single line was carried across the estuary on one of Brunel's wooden trestle viaducts on piles driven through the mud; the gradients on either side were, however, very steep, the line falling 1 in 54 from the southward down to the viaduct, and rising 1 in 64 from it to the



TRURO VIADUCT: ELEVATION.



TRURO VIADUCT: WEST WING AND ABUTMENT.

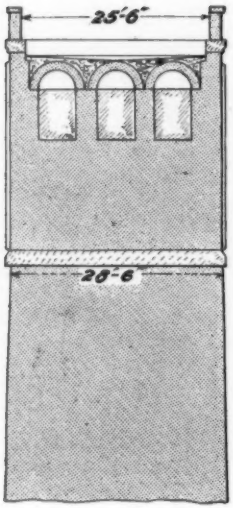
northward. This structure can be seen, in one of the photographs accompanying these notes, parallel to the new viaduct; the latter, however, is at a considerably higher level, the rails being raised 11 ft. to improve the gradients to 1 in 104 at the north end, and 1 in 95 at the south end, the viaduct itself being on the level, as was the case with the old structure.

The new viaduct, which is 1,150 ft. in length, consists of four steel spans, two of 170 ft., one of 168 ft. 9 ins., and one of 166 ft. 9 ins. opening, and six brick arched spans, each of 55 ft. opening.

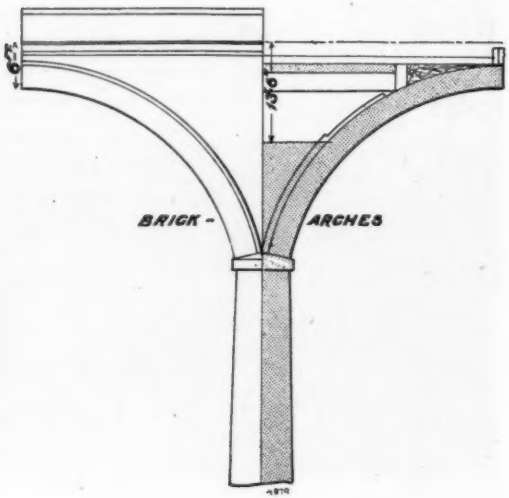
The steel spans are supported on cylinders of 12 ft. diameter below H.W.O.S.T. and 10 ft. diameter above, constructed of $\frac{3}{8}$-in. steel plates, the interior of the cylinders being filled with cement concrete and faced on the inside of the plates above the water-line with Staffordshire blue brick in cement. The mud in the estuary is of considerable depth, and it was necessary to sink the cylinders to depths varying from 45 ft. to 75 ft. below H.W.O.S.T. before a satisfactory foundation was obtained on the Devonian shale.

The cylinders are finished with cast-iron caps and ornamental pilasters carried to the top of the heel posts of the main girders. The foundations for the piers and abutments of the masonry spans were taken out in coffer-dams, exceptionally heavy timbering and temporary piling being necessary on account of the soft nature of the mud met with. The deepest of these foundations is 49 ft. below H.W.O.S.T.

The piers and abutments are of Dartmoor granite, as also are the skew-backs, string-courses and copings, and the panelled pilasters at the ends of the masonry spans, finished with rock face and drafted arrisses. The piers are 7 ft. 6 ins. in thickness at the springing, and are battered 1 in 48. The arches, spandrils, and parapets are of Staffordshire brick, the arches being segmental of 55 ft. span and 23 ft. rise, and having a thickness at the crown of eight rings of brickwork.



SECTION OF PIER.



TRURO VIADUCT.

ELEVATION AND SECTION.

The main girders in the steel spans are of the lattice pattern, with curved top booms and with steel cross-girders and rail-bearers and 3-in. jarrah-decking carrying the two lines of permanent way. The latter is of the usual type with cross sleepers, the rails being 60 ft. in length and weighing 97½ lbs. per yard.

On the eastern side, and attached to the main girders on the outside, a public footway, 6 ft. in width, has been constructed on short cantilevers, and with approaches from the main roads at Keyham and St. Budeaux, giving a direct access between the dockyards at Devonport and Keyham and the residential neighbourhood of St. Budeaux.

The viaduct is from the design of Mr. J. C. Inglis, the chief engineer, and Mr. W. Y. Armstrong, the constructive engineer. The contractors for the steelwork were Messrs. Head, Wrightson & Co., Ltd., of Westminster and Thornaby-on-Tees, and for the masonry and foundation work, Mr. J. C. Lang, of Liskeard, the latter having carried out the doubling between Devonport and the Royal Albert Bridge at Saltash, of which this viaduct forms the completing section.

The Cannington Viaduct: Axminster and Lyme Regis.

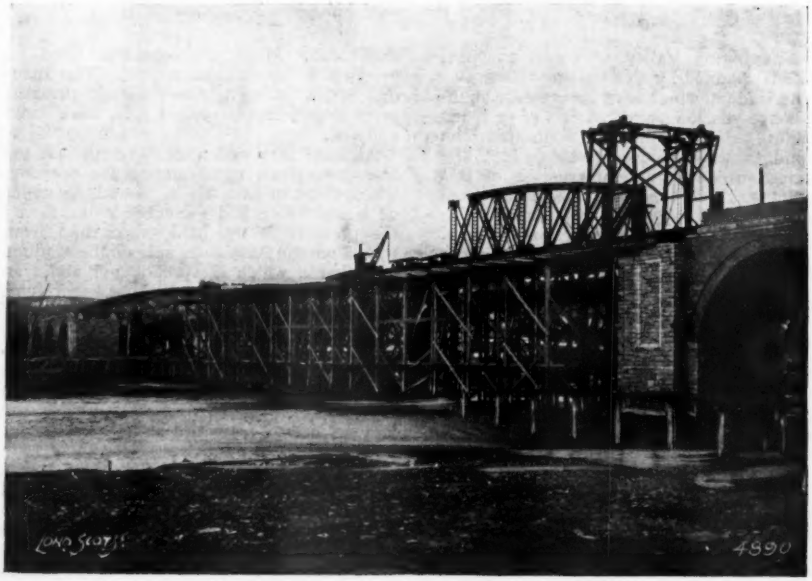
The last and not the least interesting of the viaducts to be considered is that occurring on the Axminster and Lyme Regis Light Railway. This undertaking is interesting as being constructed under the Light Railways Act of 1896, and was promoted, under the auspices of the London and South-Western Railway, to connect up the picturesque seacoast town of Lyme Regis, in Dorsetshire, with the London and South-Western trunk line to London, the connection being made at Axminster.

A ridge of hills, 500 ft. to 600 ft. above the sea-level, separates Lyme Regis from Axminster, and the abandonment of a tunnel scheme, which was at one time projected, involved the surmounting of other engineering difficulties, the most important of which was the Cannington Viaduct.

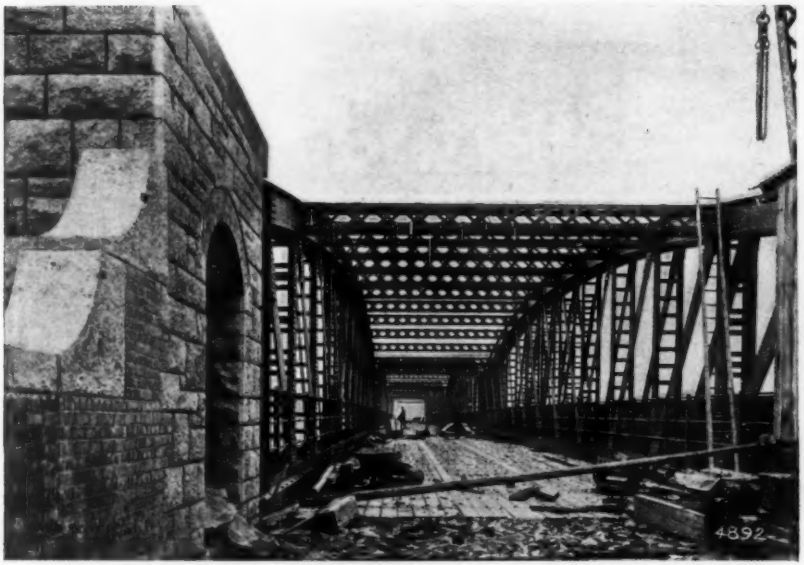
Leaving the London and South-Western Railway at Axminster Station, the line ascends, with a ruling gradient of 1 in 40, to the summit at Combpyne, a distance of 4 mls. 18 chns., at which point is the one intermediate station, situated at an altitude of 470 ft.; then the line, which is single throughout, is looped, Combpyne Station being on the island platform principle.

From Combpyne the line descends, maintaining the uniform gradient of 1 in 40, to

THE NEW WESTON MILL VIADUCT BETWEEN KEYHAM AND SALTASH.



THE WESTON MILL VIADUCT: DURING CONSTRUCTION.



LOOKING THROUGH THE WESTON MILL VIADUCT.

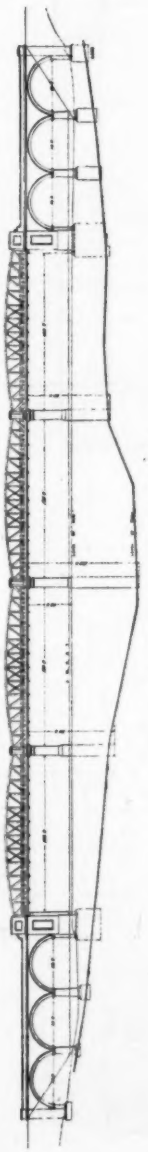
the Cannington Valley, at 5 mls. 20 chns., which is spanned by an imposing viaduct.

The viaduct, which is of concrete throughout, is 230 yds. long, and consists of 10 spans each of 50 ft., the highest point from the ground to the rail-level being 93 ft. The concrete used in the construction of this viaduct was made up of crushed flint from the adjacent cutting at Shapwilk, mixed with Portland cement in the proportion of 6 to 1, a little sand being used. When sinking for foundations, the formation was found to be mostly of wet greensand, necessitating the footing courses being spread to give a bearing of 1½ tons per sq. ft. in the worst case. On these were erected the piers of mass concrete, the work being executed in 6-ft. lifts by the shuttering method, and without the aid of scaffolding. The centerings were supported on concrete corbels, two rows of 4 each on either side of each pier being built in. It is noteworthy here to record that, when the centerings were struck, the settlement was found to be only 2½ ins. The arches, which are elliptical in form, were built of concrete blocks 3 ft. 6 ins. by 3 ft. by 2 ft. 6 ins. on the face, laid alternately, four expansion joints being provided for each arch. Mass concrete was filled in, over which dry filling is spread. The spandril walls, carrying over-sailing parapets projecting 6 ins. on either side, have been adopted.

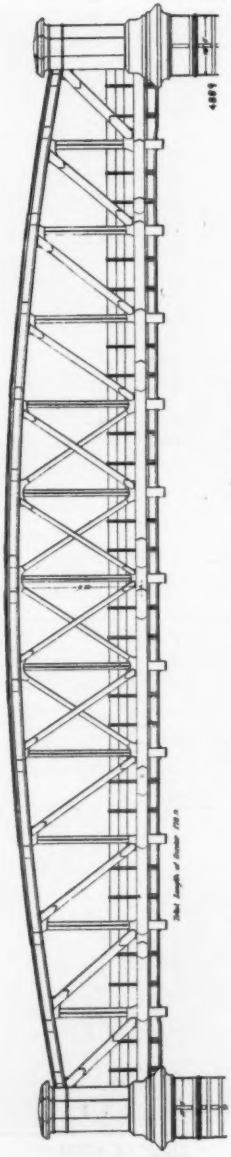
All went very well until May 7th last, the line being then nearly ready for opening, when 5 ins. of rain fell in something under 24 hours, which had the effect of increasing the pressure of the bank which had been tipped on the Axminster side of the viaduct. This bank, which is spread over about an acre, is computed to weigh about 40,000 tons, and the heavy rain caused a settlement of 1 ft. 3 ins. to take place. The extra pressure on the viaduct, resulting from that settlement, combined with the softening of the subsoil, caused the crown of the first arch to crush, and set up a severe strain on the two succeeding piers and arches.

The crown of the first arch for about 17 ft. was, therefore, cut right out in three strips, the concrete being replaced with white pressed brick built in between the two expansion joints. To further safeguard the structure two cement concrete needles, each 4 ft. by 3 ft., were put in between the piers of the second arch, as shown in the drawing.

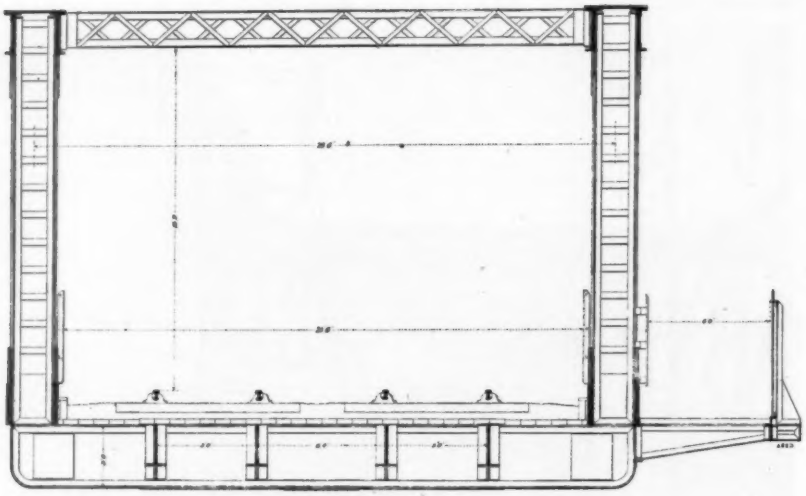
The heaviest work involved by the subsi-



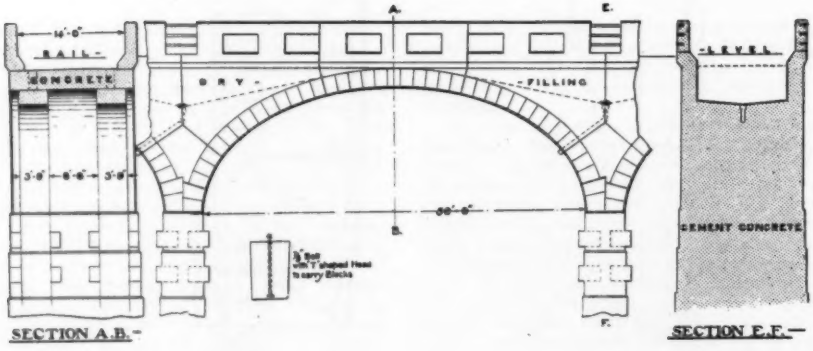
WESTON MILL VIADUCT: ELEVATION

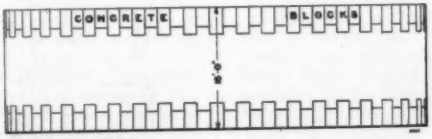


WESTON MILL VIADUCT: ELEVATION OF MAIN GIRDER.

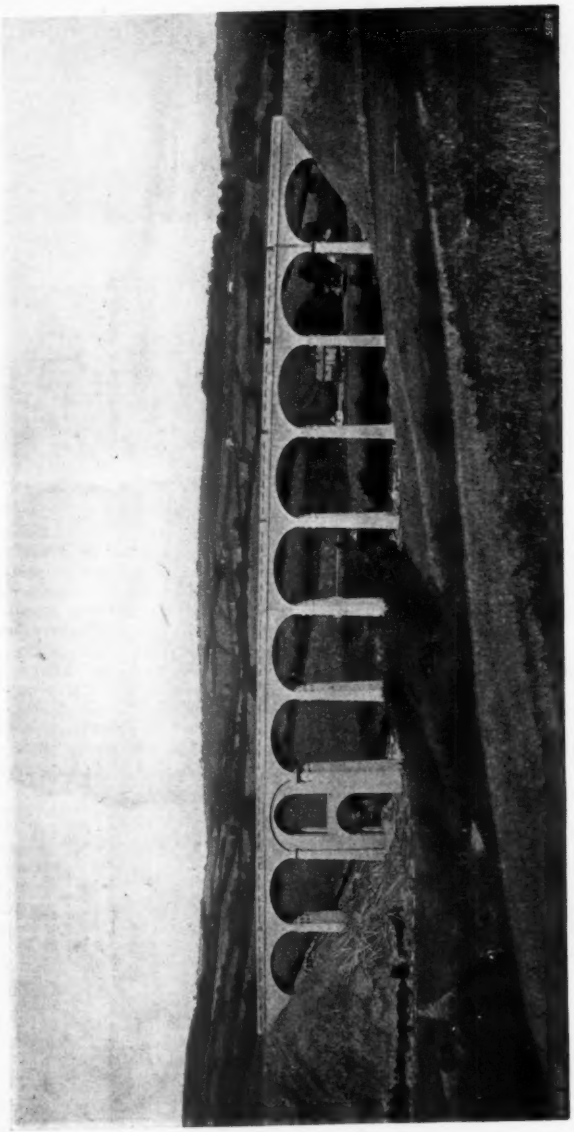


WESTON MILL VIADUCT: CROSS SECTION.

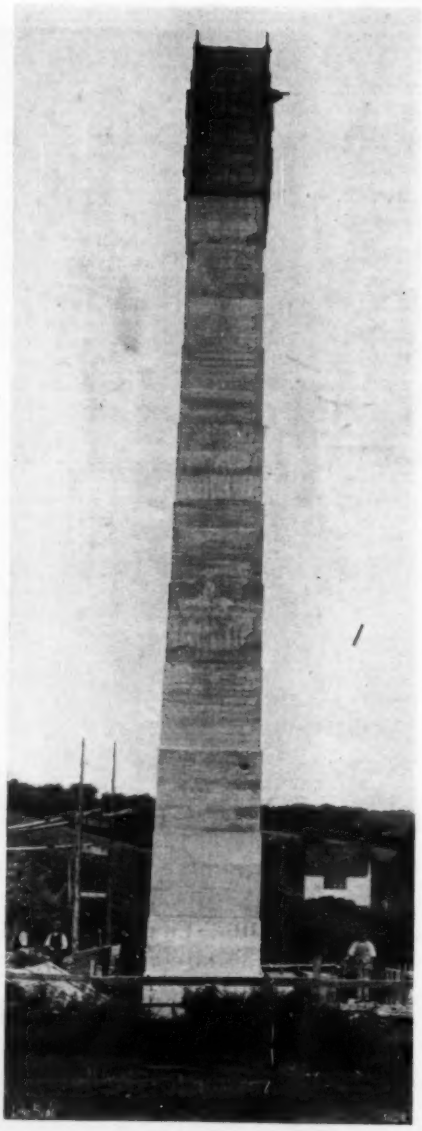




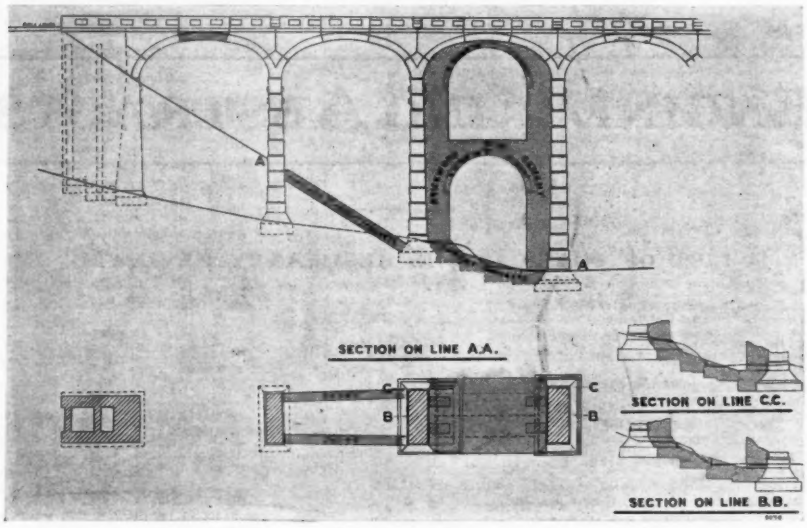
CANNINGTON VIADUCT: DETAILS OF ARCH.



GENERAL VIEW OF CANNINGTON VIADUCT.



CANNINGTON VIADUCT: ONE OF THE PIERS IN COURSE OF CONSTRUCTION.



CANNINGTON VIADUCT: DETAILS OF METHOD ADOPTED FOR STRENGTHENING THE STRUCTURE

dence was, however, in connection with the third span. Here it was decided to put in a stepped cement concrete slab between the footings, as shown, and on top of that two diaphragm walls, consisting of piers averaging 10 ft. in width, were built in of white brickwork in cement; and two semi-circular arches, one above the other, of 5 rings in cement were turned, the top one being built right up to the arch of the viaduct.

The whole work of construction was considerably accelerated by the use of one of Messrs. Jno. M. Henderson & Co.'s well-known cableways. Along the total length of the line—6 mls. 70chns.—there are altogether 22 bridges and cattle "creeps." Those calling for mention are—(1) the bridge at 4 mls. 31 chns., consisting of a flying arch over the 30-ft. cutting. It is a span precisely similar to one of the arches of the Cannington Viaduct, without, of course, the piers. (2) Walley Lane Bridge at 6 mls. 18 chns. Here, in view of the nature of the ground, no attempt at a masonry bridge was made, but a type constructed of braced piles, corrugated flooring, with a centre span of plate and angle-iron girders, was adopted.

The terminal station at Lyme Regis is on the high ground overlooking the town at an elevation of 250 ft. from the shore, with an entrance on the principal street. The work of construction was entrusted to Messrs. Baldrey & Yerburgh, Westminster, who carried it out to the plans of Mr. Arthur C. Pain, M.Inst.C.E., the engineer for the line, under the superintendence of Mr. C. Pain. The line was formally opened for traffic on August 24th last.

We are indebted for the above particulars and photographs to both these gentlemen, and for the privilege of visiting and inspecting the work to Mr. H. Jacomb Hood, M.Inst.C.E., of the London and South-Western Railway.

ENGINEERING ABSTRACTS.

LIST OF PUBLICATIONS REGULARLY REVIEWED.

Amer. Engin. & Rlrd. Jnl.	American Engineer and Railroad Journal	New York.....	20 *cts.*
Amer. Machst.	American Machinist	New York	-/4
Amer. Machy.	American Machinery	New York	-/4
Ann. Ing. Gand	Annales de l'Association des Ingénieurs de Gand	Brussels	*f.*2.50
Brit. Archt.	The British Architect	London	-/4
Brit. Claywkr.	The British Clayworker	London	-/6
Builder	The Builder	London	-/4
Bldrs.' Jnl.	Builders' Journal and Architectural Record	London	-/2
Bldng. News ...	Building News	London	-/4
Canad. Imp. Trade	Canadian Implement Trade	.....	...
Canad Mfr. ...	Canadian Manufacturer	Toronto.....	...
Coll. Gdn.	The Colliery Guardian	London	-/3
Coll. Jnl......	The Colliery Journal and Mining Engineer	London	-/6
Compte Rendu Soc. Ing. Civ.	Compte Rendu des Travaux de la Société des Ingénieurs Civils de France	Paris	*f.*3.00
Contract Jnl.	The Contract Journal	London	-/6
Ding. Poly. Jnl.	Dingler's Polytechnic Journal	Berlin	3 mos. 6 *mks.*
Echo des Mines et Métall.	L'Echo des Mines et de la Métallurgie	Paris	p.a. *f.*45.00
Écl. Élec.	ÉclairageÉlectrique	Paris	60 *f.* p.a.
Elec. Eng.	The Electrical Engineer	London	s.c. -/3 p.a. 13/-
Elec. Rev.	Electrical Review ...	London	-/4
Elec. Rev., N.Y.	The Electrical Review, N.Y.	New York.....	s.c. 10 *cts.* p.a. $5
Elec. Times ...	Electrical Times ...	London	-/2
Elec. Wld......	Electrical World & Engineer	New York.....	s.c. 10 *cts.* p.a. $6
Electrician ...	The Electrician	London	s.c. -/6 p.a. 26/-.
Electricien ...	L'Électricien	Paris	s.c. 50 *c.* p.a. 25 *f.*
Electricity	Electricity.....	London	-/1
Electricity	Electricity.....	New York.....	s.c. 10 *cts.* p.a. $4·50
Elec. Techr. ..	Der Electro-Techniker	Vienna	60 *pf.*
Elektrit.	Elektritschestvo ...	St. Petersburg	...
Elektrotek. Tiddst.	Elektroteknisk Tiddskrift	Copenhagen ...	...
Engineer	The Engineer..... ..	London	-/6½
Engineering ...	Engineering	London	-/6½
Eng. and Min. Jnl.	The Engineering & Mining Journal	New York.....	...
Eng. Gas.	The Engineer's Gazette	London	-/6
Eng. Mag.	The Engineering Magazine	New York & London	1/-
Eng. News.....	The Engineering News	New York ...	15 *c.*
Eng. Rec.	The Engineering Record	New York.....	s.c. 12 *cts.* p.a. $6
Foundry	The Foundry	Cleveland, U.S.A.	p.a. $1
Gas Wld.	The Gas World	London	-/3
Gas	Le Gaz	Paris	1 *f.*
Gén. Civil	Le Génie Civil.....	Paris	s.c. *f.* 1.00 p.a. *f.*45.00
Glückauf.....	Glückauf	Essen a.d.Ruhr	...
Ice and Cold Storage	Ice & Cold Storage	London	-/6
Ind. Elec. ...	L'Industrie Électrique	Paris	s.c. *f.* 1.00 p.a. *f.*26.00
Iron and Coal Trades Rev.	Iron and Coal Trades' Review	London	-/6
Iron and Steel Trades Jnl.	Iron and Steel Trades' Journal	London	-/3

Jnl. Gas Lighting	The Journal of Gas Lighting	London	-/6
Jnl. Assoc. Eng. Soc.	Journal of the Association of Engineering Societies	Philadelphia, U.S.A.	...
Jnl. Franklin Inst.	Journal of the Franklin Institute	Philadelphia, U.S.A.	30 *cts.*
Jnl. I. E. E. ...	Journal of the Institution of Electrical Engineers	London	Varies
Jnl. Iron & Steel Inst.	Journal of the Iron and Steel Institute	London	16/- per vol. (two annually)
Jnl. San. Inst.	Journal of the Sanitary Institute	London	...
Jnl. Soc. Arts	Journal of the Society of Arts	London	6*d.*
Jnl. Western Soc. Eng.	Journal of the Western Society of Engineers	Chicago, U.S.A.	...
Knowledge	Knowledge	London	-/6
Light Rly. & Tram. Jnl.	Light Railway and Tramway Journal	London	1/-
Machinery ...	Machinery	New York.....	25 *cts.*
Marine Engr.	Marine Engineer ...	London	1/-
Marine Engg.	Marine Engineering	New York.....	25 *cts.*
Mech. Wld. ...	Mechanical World	Manchester...	-/1
Métallurgie ...	La Métallurgie	Paris	p.a. *f.*20.00
Mines and Minerals	Mines and Minerals	Scranton, Pa.	20 *cts.*
Mit. Verein. Strassenbahn.	Mittheilungen des Vereines für die Förderung des Local- und Strassenbahnwesens	Vienna	...
Mod. Machy.	Modern Machinery	Chicago	10 *cts.*
Nat. Ldry. Jnl.	National Laundry Journal	Chicago	15 *cts.*
Nature	Nature	London	-/6
Power	Power.....	New York.....	20 *cts.*
Proc. Am. Soc. C.E.	Proceedings of the American Society Civil Engineers	New York.....	...
Proc. Can. Soc. C.E.	Proceedings of the Canadian Society of Civil Engineers	.....	...
Proc. Inst. C. E.	Proceedings of the Institution of Civil Engineers	London	Not sold; Mbrs. only
Proc. I.Mech. E.	Proceedings of the Institution of Mechanical Engineers	London	Mbrs. only
Proc. Roy. Phil. Soc. Glasgow	Proceedings of the Royal Philosophical Society of Glasgow	Glasgow	Mbrs. only
Pub. Health Eng.	Public Health Engineer	London	-/3
Quarry	The Quarry.....	London	-/6
Rev. Tech	La Revue Technique	Paris	1 *f.*
Rlrd. Gaz.	The Railroad Gazette	New York.....	p.a. $6'08
Rly. Age	The Railway Age ...	Chicago	10 *cts.*
Rly. & Engg. Rev.	The Railway and Engineering Review	Chicago	10 *c.*
Rly. Mastr. Mech.	Railway Master Mechanic	New York ...	s.c. 10 *cts.* p.a. $1'00
Rev. Chim. Ind.	La Revue de Chimie Industrielle	Paris	p.a. *f.*12.00
Sc. Amer.	Scientific American	New York.....	8 *cts.*
Stahl u. Eisen	Stahl und Eisen.....	Dusseldorf ...	p.a. 24 *mks.*
Steamship	The Steamship	Leith	-/6
Stev. Inst. Indic.	Stevens' Institute Indicator	Hoboken, N.J.	50 *cts.*
Street Rly. Jnl.	Street Railway Journal	New York.....	s.c. 50 *cts.* p.a. $6.00
Surveyor	Surveyor	London	-/3
Techy. Quarty.	Technology Quarterly	Boston	75 *c.*
Tek. Tidst......	Teknisk Tidskrift	Stockholm ...	13'75 *kr* p.a.
Tram. & Rly. Wld.	The Tramway and Railway World	London	1/-
Trans. Am. I. E.E.	Transactions of the American Institute of Electrical Engineers	New York.....	...
Trans. Am. Soc. Mech. E.	Transactions of the American Society of Mechanical Engineers	New York.....	...
Trans. Am. Soc. Nav. E.	Transactions of the American Society of Naval Engineers	New York.....	$5 p.a.
Trans. Civ. Mech. E. Soc.	Transactions of the Civil and Mechanical Engineers' Society.	.....	...
Trans. Inst. Eng. & Shipbldrs.	Transactions of the Institution of Engineers and Shipbuilders in Scotland	Glasgow	...
Trans. Soc. E.	Transactions of the Society of Engineers	.....	...
Westn. Electn.	Western Electrician	Chicago	10 *cts*
Zeitschr. Vereines Oster. Ing. und Arch.	Zeitschrift des Oestereichischen Ingenieur und Architekten-Vereins	Vienna	60 *kr.*
Zeitsch. Vers. Deutsch. Ing.	Zeitschrift des Vereins Deutscher Ingenieure	Berlin	1 *m.* 40 *pf.*
Zeitsch. Elektrotechnik.	Zeitschrift für Elektrotechnik	Vienna	p.a. 20 *mks*
Zeitsch. Elektrochemie	Zeitschrift für Elektrochemie	Halle à S., Germany	4 *mks.* per qr

Any of the above-mentioned publications can be obtained on application to Messrs. Williams & Norgate, Henrietta Street, Covent Garden, London, W.C.

MATERIALS AND MEASUREMENTS.

Porcelain for Electric Work.

SEMI-VITRIFIED porcelain does not possess very great insulating properties, even if it is perfectly dry. On the contrary, when completely vitrified, a plate only 3 mm. thick is able to resist a tension of 40,000 volts. Porcelains of which the external appearance is equally good often possess very different insulating properties. The essential qualities of porcelain for electrical work are—(1) Resistivity to be as high as possible; (2) mechanical resistance to be sufficient for resisting tension exerted by the conductors and for withstanding violent shocks without fracture. Porcelains of which the resistivity is the highest contain a large quantity of silica proportionately to alumina. If the proportion of potash is increased and that of lime diminished, the result is that the material becomes friable and fragile; therefore the quantity of lime should only be reduced proportionately to the reduction of potash. About 20 per cent. of lime is sufficient to give the qualities necessary for mechanical resistance; and it appears necessary that the proportion of silica should not be less than 6·2 parts to 1 part of alumina. In order to secure porcelain possessing adequate mechanical resistance it is necessary to observe the proportions of between 40 per cent. of potash to 60 per cent. of lime, and 80 per cent. of potash to 20 per cent. of lime. —**A. Bainville,** *L'Electricien, Vol. XXV., Second Series, No. 650,* pp. 375–377.

The Testing of Bitumen.

IN testing asphalts to determine the action of water upon them, the author coats a piece of glass with the paving cement, immerses it in water and examines it from time to time for evidences of discoloration. Another method is to make two cubes of the cement, immerse one in water and leave the other in air, and compare their weights and dimensions from time to time. All asphalts, if exposed to the continual action of water, will rot. The action of water on asphalt was of importance formerly, but engineers now grade their streets so that water will not stand on them. It is necessary to keep water away from the under surface of an asphalt pavement, and the author criticised the Washington authorities for using a 1 : 4 : 10 concrete base for asphalt. Water will work through such a concrete and ruin the asphalt. Gas from leaky mains is also ruinous to asphalt, and water and gas together are far more destructive than either alone. One valuable practical point brought out in discussion of the paper by Mr. Richardson, was the impossibility of making a bond between asphalt and cold concrete. In applying asphalt to concrete or masonry, first paint the surface, which must be perfectly dry, with asphalt dissolved in naphtha. The asphalt can then be laid against this surface and will adhere.—**A. W. Dow,** *Am. Soc. for Testg. Materials. Report Eng. News, Vol. L. No. 2,* pp. 32–33.

Protective Coatings for Iron and Steel.

THE surface for painting must be free from grease and dirt, and mill scale and rust must be removed. The use of the sand blast is recommended, but is not always necessary. Paint coatings should be as thick as possible, brush marks should flow out, and the paint should not contain any large amounts of volatile matter. Whether paint coats shall dry in 6 or 24 hrs. must be determined by the contingencies of the case, but as much time as possible should be allowed between coats. It is however, considered practicable to have an efficient metal coating dry in 8 hrs. The under coatings must not be softened or acted upon by the subsequent coats of paint. The coating must protect, and must have the maximum impermeability to moisture, air, and carbon dioxide. As iron and steel will not rust in dry air, or in water free from air and carbon dioxide, the best protection is the most impervious coating. The pigment should be as finely ground as possible, and the vehicle and pigment must be water repellent. Coatings should be efficient under ordinary conditions for five years. The durability measures the life of the coating, and it should therefore adhere to the metal through all ranges of contraction and expansion without peeling or cracking. Neither the pigment nor the vehicle should cause a disintegration of the coating, and the coating should not be affected by products necessary for the maintenance, equipment, or use of the structure protected. The coating should resist the mechanical injury due to sand, cinders, and other material carried by the wind. A satisfactory coating must permit recoating when needed without additional labour for cleaning and removing old coat. The general cause of failure of coatings to protect is moist air and carbon dioxide. Dilute acids, have far less action on paint films than alkaline solutions. Strong acid solutions rapidly destroy the coating, but it is rare that such conditions exist. Tests should be adapted to the demands of service conditions, and divided into three broad classes :—(1) Actual service tests, under normal conditions, applied to structure to be protected. (2) Accelerated tests, applied to specially prepared surfaces, and subjected to abnormally severe conditions. (3) Chemical tests to determine the constituents and adulterations of the pigment and vehicle, as far as the knowledge of the subject will admit.—**S. S. Voorhees,** *Am. Soc. for Testing Materials, Report Eng. News, Vol. L., No. 2,* p. 30.

CONSTRUCTIONAL.

A Reinforced Concrete Floor.

THE car "barn" described by the writer was built for the Mahoning Valley Railway Company. The concrete steel floor is used between the tracks over the pits, which are thus kept open over the entire

space. By this method workmen are free to pass from one track to another without climbing up to the floor level and down again; the space for working is more than doubled, and ample space is provided for lighting wires and heater pipes without encroaching on the working space in the pit proper. The rails are supported on masonry piers spaced 10 ft. apart, leaving 5 ft. open space every 10 ft. The piers were built to the level of the rail bottom, whereupon the rails were placed in position, properly aligned, and brought to correct surface with wooden wedges. Strips of ¾-in. by ¾-in. wire netting were then placed under the rails over each pier, and the space grouted with 1 to 1 mortar. After the centering was in place a layer of 1 to 3 cement mortar was placed, then ½-in. "Thacher Pat." rods were laid transversely 6 ins. apart, with the ends extending over the flanges of the rails; then 3½-in. "Thacher Pat." bars were laid longitudinally, one in the centre of the span and one 6 ins. from each rail. These longitudinal bars are not required for strength, but give an added toughness and an increased factor of safety to the floor by distributing a given load over a larger area. After the rods were placed, the space between the rails was filled with 1 to 24 concrete. This was tamped down and the surface covered with 1 to 2 mortar. The spans covered by the floor are 7 ft 6 ins. in one-half of the barn, and 9 ft. in the other half, measuring from centre to centre of rails. The thickness was 4¾ ins. at rails, and 5 ins. at centre. The floor should have a strength of 115 lbs. for 9-ft. spans; and 135 lbs. for 7½-ft. spans.—**G. M. Scofield,** *Proc. Eng. Soc., W. Pa., Vol. XIX., No. 3,* pp. 141-143.

Concrete Foundations.

For footings and piers concrete surpasses brick or rubble, both in excellence and cheapness. The concrete must be built up in layers of from 4 to 6 ins., and each layer thoroughly compacted by iron rammers. It is rammed sufficiently when the water comes to the top. The concrete should also be washed down along the edges of the forms with a spade to insure a neat-looking job on the outside. The best concrete is machine mixed. The forms for concrete work must be strong, tight, and smooth on the inside. When designing foundations, the different walls and piers should be made as nearly alike as possible, so that the forms can be made in sections and reset for new piers without alterations. If possible, foundations should rest on hard pan, gravel, or hard clay. Made ground should be shovelled out for a depth of at least 12 ins. below the bottom of the foundations, and rammed as hard as possible. The 12 ins. should then be filled with clay puddle, well rammed in place. If the bottom course of the foundations rests in water, the concrete must be treated a little differently. If there are only a few inches of water, the concrete may be mixed dry and dumped carefully into the trench and slightly rammed. Should the water be much deeper, the concrete may be mixed as for ordinary work, tied up in jute sacks, and the sacks laid closely in the trench, taking care to bond them together in the fashion of brickwork. After the foundations are finished to within ½ in. of the top, a layer of rich cement mortar should be put on, and swept off perfectly level with a straight-edge. After this mortar has taken its first set it may be smoothed with a trowel. The sides may also be plastered with the same mortar, and after it has taken its first set lined off to resemble stone. For important work the foundations should be arranged with tunnels and pockets, so that the bolts may be pushed down through the holes and the nuts and washers put on from below. When the threads extend into the concrete, they should be well oiled to prevent the concrete sticking to them, if it is expected to use the thread for adjustment. In estimating the cost of concrete, the following table may be of value. It might be well to note in the table the fact that from 1 : 2 : 4 to 1 : 3 : 6 are the limits for first-class work, and from 1 : 2½ : 5 to 1 : 4 : 8 for second-class work. The weaker mixtures are to be used for filling, or where the object is weight rather than great strength.

Proportion.			Required for 1 Cub. Yd.		
Cement.	Sand.	Gravel.	Bb. 1 Cement.	Cub. yd. Sand.	Cub. yd. Gravel.
1	2	4	1·34	0·41	0·81
1	2	5	1·17	0 36	0·89
1	2½	5	1·10	0 42	0·83
1	3	5	1·03	0·47	0·78
1	3	6	0·92	0·42	0·84
1	3½	7	0·80	0·43	0·85
1	4	8	0·71	0·43	0·86

R. P. King, *Machinery, Vol. IX., No. 12,* pp. 613-615.

The Theory of Skew Arches.

The writer indicates what seems to be the proper method of going into the safe and economical design of this kind of structure, and an explanation of what Prof. Kernot* finds to be true regarding the location and direction of maximum stresses. In the first place it appears wrong to assume that any lamina of a skew arch taken longitudinally, parallel to either face, is the same as a lamina of a symmetrical arch. In general a skew arch appears to contain a simple or symmetrical arch, as indicated in the Fig. 1—the portion *H E F G*—which can only be obtained when the section considered be taken at right angles to the axis or the straight-line elements of the arch ring and cuts both abutments as shown. This portion *HEFG* is evidently the dangerous section, for it must carry not only

* Feilden's Magazine, Vol. IX., No. 2, pp. 162—164.

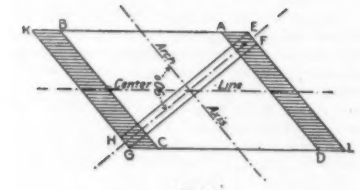


FIG. 1.

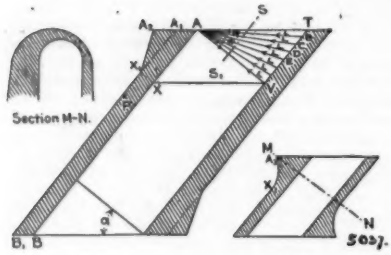


FIG. 2. FIG. 3.

SKEW ARCHES.

the loads coming upon it, but must partially support, by vertical and horizontal shear (in the sections *H E* and *G F*), the loads coming upon the parts *G F L* and *K E H*. According to mechanics we should consider the skew-arch bridge as made up of the parts *H E F G*, *G F L* and *K E H*, and consider each separately as a free body, supplying as external forces the reactions of the adjacent portion or portions, the foundation, backing of abutments, loads, etc., and determine what the reactions of *K E H* or *G F L* are upon *H E F G*. Then design *H E F G* to resist its own loading and these reactions. Any other section made at right angles to the arch axis and outside the portion *H E F G* will have less and less stresses transmitted across itself as that section approaches the points *K* and *L*, less stresses in the abutments here (as shown by Mr. Kernot), and, of course, a less thickness of abutment is required. It is surprising that skew-arch abutments have been built in the old form until this day, instead of the form recommended by the aforenamed writer.*—**W. E. Miller,** *Eng. News, Vol. L., No. 2*, p. 38.

Portland Cement and Blast-Furnace Slag.

THE author discusses the question as to whether pure, genuine Portland cement, on being mixed with granulated blast-furnace slag, remains a pure material or is degraded to a low-class mixture product. From an investigation, both mechanical and chemical, it is inferred that blast-furnace slag is identical with Portland cement, and the author thinks it to be gratifying that modern industry has succeeded in increasing gradually the value of blast-furnace slag, so that this product, which once upon a time was regarded as valueless refuse matter, may be now of the highest use to the structural engineer.—**D. H. Passow** *(Paper read before the 5th Intern. Congress for Appl. Chem.;* see *Stahl u. Eisen, Vol. XXIII., No. 15*, pp. 878–891). —*A. G.*

The Fatigue of Cement.

IN the course of the past year a series of over 100 crushing tests on 2-in. moulded blocks was carried out at Washington University, with a view to discovering the effect of repeated stress. The blocks were of neat cement, and the tests for failure under repeated load were made with successively lower percentages of the quiescent-load ultimate load. The curve of strength for varying numbers of repetitions thus obtained shows a remarkable similarity to the fatigue-curves of iron and steel. As far as the limits of the tests permit of conclusions, the curve appears to be asymptotic to the line of about 50 per cent. of full strength.—**Prof. J. L. Van Ornum,** *Am. Soc. for Testg. Materials, Report Eng. News, Vol. L., No. 2*, p. 35.

Stresses on Skew Arches.

IT seems that the inequality of stresses, as shown by Prof. Kernot* in a mechanical way, can also be proven analytically, and an approximately true method of designing the arch given. In Fig. 2 let the arch ring be divided in curved wedge elements, bounded by planes—shown in plan by the lines *A B*, *A C*, etc. We can imagine these arch elements as a series of horizontal beams—or, better still, as king-post trusses with the horizontal members omitted. This will not change the amount of the stresses reaching the abutments. The stresses of the load on the structure and the reactions from the abutments must go in the directions of these lines, as shown respectively by the arrows *L* and *R*. In the case of the arch these stresses will produce a shear between the elements bounded by the lines *A B*, etc., and the unit shear in any radial plane parallel to the axis as *s s* will decrease from *S* towards *s*, as the elements starting from the face of the arch decrease in area going towards *A V*. Also the unit shear and compression in these radial planes will decrease moving towards the other abutment. These load stresses will not all go (as indicated) to the point *A*, but will be distributed on the abutment from *A* towards *B* by the internal resisting shears. Theoretically this shear will be zero when we reach an element which lies at right angles with the planes of the face walls; and the abutment between the point *A* and some point towards *B* must carry all the loads transmitted through these oblique elements. We may now draw a typical section of the arch ring in the plane of the springing line (see Fig. 3), but we do not know whether $A_2 x$ will be a concave, a convex, or a straight line; it will vary so little from a straight line that either waste of masonry or loss of strength will be of little consequence. A practical way to design the arch would be to determine the thickness of the arch ring and abutment at the springing line at the point *P* by the methods in use for designing

* FEILDEN'S MAGAZINE, Vol. IX., No. 2, pp. 162–164.

right arches. Then, considering the triangular portion AVT in Fig. 2, if the arch was symmetrical the centre of gravity of its loads would be approximately two-thirds of the span distant from A towards the other abutment; but as the ring is heavier on the side next A, let us consider the resultant of the loading to be in the centre of the span. The increase of the load on A due to the triangular part of the arch can then be found approximately by taking moments around VT. Suppose this will require the additional thickness A_1, A_2; then AA_2 is the thickness of the abutment and arch on the springing line. This dimension of AA_2 may require a new position for the resultant of the loads on the triangular part. We can then take moments a second time, which will give a dimension for A_1A_2 near enough for the purpose. To locate X: Lay off the distance TV=span by tangent a, from A towards B, and draw A_2A and BB_1, X_1, A^2. A will be a section of the abutment and arch ring at the springing line. The writer admits there is not much mathematical basis for this method of locating X, but it is one of those cases which Trautwine speaks of.—**J. A. Paige,** *Eng. News, Vol. L., No. 2,* p. 38.

METALLURGY.

The Influence of Silicon on Iron.

THE author publishes the results of a very complete investigation of a series of alloys of exceptional purity. These results offer many features of interest, and very clearly show that silicon cannot be classed among the highly injurious elements, for an alloy containing 1 per cent. actually gave a tenacity of 30 tons per sq. in., an extension of 36 per cent. on 2 ins., and a contraction of area at the point of fracture of 67 per cent. The analyses and complete mechanical tests are given in the accompanying table. It may be noted that the term "rolled" applies to the bars in the condition in which they left the rolls, "normal" applies to bars of the rolled material which have been raised to a temperature of 1,000 degs. Cent., and then allowed to cool in air, whilst "annealed" represents rolled bars which have been heated to a temperature of about 950 degs. for 40 hours, and then allowed to cool down over a further period of 170 hours.

The following tests represent the mean of duplicate results, and from them the influence of silicon on the mechanical properties of iron may be sum-

Analysis.						Condition.	Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 ins.	Reduction of Area per cent.
C.	Si.	Mn.	Al.	S.	P.					
0·044	0·024	0·036	0·01	0·03	0·014	Rolled	20·09	24·52	40·2	68·3
,,	,,	,,	,,	,,	,,	Normal	11·60	22·56	43·0	67·0
,,	,,	,,	,,	,,	,,	Annealed	19·87	22·62	47·0	71·5
0·38	1·020	0·079	0·016	0·038	0·019	Rolled	27·08	30·77	36·7	67·4
,,	,,	,,	,,	,,	,,	Normal	24·63	30·57	35·5	66·8
,,	,,	,,	,,	,,	,,	Annealed	20·04	27·18	40·2	76·2
0·039	2·125	0·040	0·048	0·029	0·020	Rolled	27·85	35·39	28·0	45·4
,,	,,	,,	,,	,,	,,	Normal	21·42	32·60	25·0	23·7
,,	,,	,,	,,	,,	,,	Annealed	19·84	30·00	39·2	65·9
0·038	2·903	0·061	0·069	0·041	0·018	Rolled	29·74	37·40	15·5	14·6
,,	,,	,,	,,	,,	,,	Normal	27·36	31·34	4·2	4·1
,,	,,	,,	,,	,,	,,	Annealed	21·29	33·90	35·5	60·0
0·038	4·026	0·062	0·091	0·033	0·018	Rolled	Coincides	41·76	nil	nil
,,	,,	,,	,,	,,	,,	Normal	with maxi-	36·53	,,	,,
,,	,,	,,	,,	,,	,,	Annealed	mum stress	43·56	2·2	2·8
0·040	4·885	0·072	0·141	0·027	0·021	Rolled	Coincides	41·67	nil	nil
,,	,,	,,	,,	,,	,,	Normal	with maxi-	36·34	,,	,,
,,	,,	,,	,,	,,	,,	Annealed	mum stress	41·46	,,	,,
0·038	5·998	0·061	0·098	0·032	0·020	Rolled	Coincides	20·03	nil	nil
,,	,,	,,	,,	,,	,,	Normal	with maxi-	16·12	,,	,,
,,	,,	,,	,,	,,	,,	Annealed	mum stress	26·58	,,	,,
—	7·470	0·210	0·050	0·011	0·019	Rolled	Coincides	23·90	nil	nil
—	,,	,,	,,	,,	,,	Normal	with maxi-	20·69	,,	,,
—	,,	,,	,,	,,	,,	Annealed	mum stress	21·06	,,	,,

marised as follows. Although the addition of silicon to iron increases the elastic limit and tenacity of iron, such increase is only obtained by loss of ductility, which loss, providing the material has been well annealed, is very small until the silicon reaches 3 per cent., after which it becomes great, the ductility almost reaching zero with 4 per cent. silicon. All the alloys rolled clean and sound up to 7·47 silicon, and from the finished bar were scarcely distinguishable from bars of the best tool steel. Alloys containing over 5 per cent. silicon demand skill and care in machining in order to avoid fracture. Pyrometric observations of the pure iron show the critical points, Ar_3, Ar_2, and Ar_1 at 850 degs. Cent., 740 degs. Cent., and 673 degs. Cent. respectively. The addition of 1·2 per cent. silicon entirely eliminates Ar_2, as already shown by Osmond and Arnold, and lowers the temperatures at which Ar_3 occurs to 733 degs. Cent. Successive additions of silicon still further lower the position of Ar_3, until with 7·5 per cent. silicon it occurs at 678 degs. Cent. The temperature at which Ar_3 occurs, the displacement of Ar_3, and the calculated displacement per 1 per cent. silicon are embodied in the following table :—

Silicon %.	Temperature at which Ar_3 occurs.	Displacement.	Displacement per 1 % Silicon.
0·02	740° C.	—	—
1·03	733° C.	7°	6·8°
1·94	725° C.	15°	7·7°
2·90	713° C.	27°	9·3°
4·50	703° C.	37°	8·2°
4·89	694° C.	46°	9·4°
7·47	678° C.	62°	8·3°

The magnetic properties of these alloys are of importance in the manufacture of mild steel for dynamos and transformers. The author's results obtained from annealed specimens, are tabulated as follows :—

Silicon %.	Maximum Induction, H=20.	Permeability for H=4.	Retentivity.	Coercive Force.	Energy Dissipated per Complete Cycle.
0·02	16,000	2,325	8,375	1·8	10,550 energies per cycle
1·02	16,200	2,562	8,000	1·7	8,789 ,, ,,
2·90	15,500	2,750	7,325	1·5	8,081 ,, ,,
4·89	14,750	2,665	7,200	1·2	6,110 ,, ,,
7·47	14,000	2,937	9,000	1·0	5,613 ,, ,,

It will be seen from this table that as the percentage of silicon increases the permeability for low magnetic fields increases, and the coercive force and hysteresis loss decrease. — **Thos. Baker, M.Sc.,** *Proc. Iron and Steel Inst., Sept., 1903,* pp. 1-19.—*P.L.*

The Burning and Overheating of Steel.

The author concludes that the burnt structure of very much overheated steel is largely due to the partial melting of its more fusible constituents. This melting causes brittleness directly and indirectly by the admission of oxygen to the steel. According to the American metallurgists the latter stage would alone be called burning, but as the effect of partly melting the steel is quite distinct from that of overheating below the zone of partial fusion, the author would prefer to apply one word to the whole of the changes that take place in this zone. If the word burning is still employed, it should be remembered that it is essentially a partial melting of the steel though often accompanied by oxidation. The following stages have been recognised :—(1) Overheating (below the point of incipient fusion). (2) Partial melting, called burning—(*a*) merely producing segregation of carbon in the joints; (*b*) accompanied with liquation and producing flaws; (*c*) further liquation and oxidation in the flaws. (1) Steel that has been merely overheated can be completely restored by heating just above its highest recalescence point and allowing to cool. (2) Steel in stage (*a*) can be restored by suitable annealing; in stage (*b*) forging would also be necessary, and in stage (*c*) it would be restored with difficulty, if at all. — **Prof. A. Stansfield, D.Sc., A.R.S.M.** *Carnegie Research Scholar, Proc. Iron & Steel Inst., Sept., 1903,* pp. 1-36.—*P. L.*

Sorbitic Steel Rails.

From a micrographic point of view sorbite is characterised by the absence of striæ, and by the property of colouring rapidly by polish attack or by tincture of iodine. The distinctive properties conferred by the presence of sorbite are shown in oil-quenched steel and in patented wire. On studying the effect of oil-quenching, the authors found that the proportion of sorbite is great or small according to the size of the mass quenched, thus the central portions of large masses contain much less sorbite than the exterior portions. If, on the other hand, the section of steel quenched is very light, some of the more brittle constituents of steel may be present in addition to sorbite. Steel-wire rods after passing through the patenting process—which consists in heating to a temperature at which steel "scales," and then cooling more or less rapidly through the critical points—contain large quantities of sorbite readily

detected by the microscope. The property of enabling the patented rod to be drawn to a much greater fineness than is possible in the unpatented material is undoubtedly due to the sorbite present. The authors concluded that if sorbite is responsible for the high qualities of oil-quenched steel and negatively quenched wire-rods, there is no reason why it should not be produced in steel rails with equally beneficial results. With this object in view, many experiments were conducted on 5-ft. lengths of rail. In the initial experiments the rails, instead of cooling normally, were plunged into hot or cold water and afterwards reheated to a barely visible red heat, that is, a temperature of about 500 degs. C. Test results from these experiments were entirely satisfactory, and further ones were therefore undertaken with a view to avoid the reheating. In the course of these experiments it was found that by quenching the heads only of the rails to a point under Ar_1 and then allowing the residual heat to do the tempering, a sorbitic structure resulted. The results of the later work show clearly that, by partially quenching the heads and allowing the rails to temper themselves, an improved tenacity results, and although the elongation is decreased the contraction of area remains practically the same. A normal rail of 37 tons tenacity when made sorbitic is increased to 45 tons without diminution of the contraction of area. A rail of 36½ tons tenacity is increased to 49 tons with a slight increase in the contraction of area, and one of 43 tons is raised to 50 tons with a slight decrease in the contraction of area. Pieces cut from the area of maximum sorbite, on being tested by repeated reversals of strain, show greater toughness and endurance than the normal materials. Finally, the authors point out that whilst it is easy to treat hot rails in short pieces they have not yet completely succeeded in treating 30-ft. lengths satisfactorily. The work, however, is by no means complete, and the authors hope in the course of a short time to report a complete success.—**J. E. Stead, F.R.S.,** and **A. W. Richards,** *Proc. Iron & Steel Inst., Sept. 1903,* pp. 1–14.—*P. L.*

Some further Experiments on the Diffusion of Sulphide through Steel.

A STUDY of the author's present experiments sustain his previous conclusion that oxysulphide of iron is capable of diffusing through steel without the latter having its sulphur content appreciably increased. In an earlier paper it was shown that a temperature of over 1,200 degs. Cent. is most favourable to this diffusion. The experiments conclusively show that iron is permeable by sulphides about 1,200 degs. Cent, but, whilst the fact has been established, sufficient data has not yet been obtained from which to give a positive explanation of the manner in which sulphides permeate or diffuse through iron. The most plausible hypothesis would seem to be that the sulphides originally present in the iron fill more or less completely the interstitial spaces between the crystals of iron; that above 1,200 degs. these sulphides are very fluid and may be drawn out of the steel by capillary action of some absorbent, such as asbestos, and their place taken by other sulphides, providing these latter are sufficiently mobile to find their way into the extremely minute spaces between the crystals.—**E. D. Campbell,** *Proc. Iron & Steel Inst., Sept. 1903,* pp. 1-12.—*P. L.*

Nickel Steel for Purposes of Construction.

THE addition of nickel to a steel gives a two-fold advantage; first, the strength and ductility of a steel of given carbon content are increased; secondly, it permits the use of a higher carbon content and therefore a stronger steel, this on account of the greater endurance under shock that nickel imparts to steel. This resistance to shock is taken advantage of in the universal adoption of nickel-steel for armour plates where a single enormous shock must be met. Experiments have been made by the United States Testing Bureau, comparing the endurance under vibratory and repeated alternating stresses of nickel-steel with that of wrought-iron and various steels. These results are shown in tabular form as follows:—

Under a fibre stress of 40,000 lbs. per sq. in.

	Alternations of Stress.
Wrought iron, breaks after ...	59,000
0·15 % carbon steel, breaks after...	170,000
0·25 % ,, ,, ...	229,000
0·35 % ,, ,, ...	317,000
0·45 % ,, ,, ...	976,000
3½ % nickel, 0·25 to 0·30 % carbon steel, breaks after	1,850,000
4½ % nickel, 0·25 to 0·30 % carbon steel, breaks after	2,360,000
5½ % nickel, 0·25 to 0·30 % carbon steel, breaks after	4,370,000

Hitherto the bulk of experiment on rolled nickel-steel has been on medium steel of about 0·20 to 0·25 per cent. carbon and 3 per cent. nickel. To test the applicability of a higher carbon steel for structural purposes the Carnegie Steel Company made a heat of the following composition:—

C.	P.	Mn.	S.	Ni.
0·35	0·022	0·68	0·022	3·24 %

This heat was rolled down into plates of various gauges, angles, rounds, eye-bar flats and forged into axles. A number of tensile test pieces were cut from each of these sections, and the average of the results obtained are as follows:—

	Elastic Limit in lbs. per sq. in.	Ultimate Strength in lbs. per sq. in.	Elongation % on 8 ins.	Reduction of Area %
Average of 16 sections	70,400	103,000	17·4	39·2
Average of annealed specimens	56,950	82,600	23·35	51·1

Standard specifications for medium structural steel demand a tensile strength of from 60,000 to 70,000 lbs per sq. in., an elastic limit not less than one-half of the ultimate strength and an elonga-

tion of 8 ins. of 22 per cent. The average elastic limit of the foregoing nickel-steel is approximately the tensile strength of medium structural steel, its tensile strength has been increased by about 50 per cent. and the elongation diminished by only 20 per cent. The elongation in a rolled carbon steel of 100,000 lbs. per sq. in. tensile strength is not more than 12 per cent. The elastic limit of annealed nickel-steel eye-bars, as shown by full-sized tests, exceeds the present specification by over 50 per cent. Their substitution for carbon-steel eye-bars would effect a saving—based upon a comparison of their elastic limits—of about one-third the weight of the eye-bars. The adoption of nickel-steel shapes for the other important members in bridge design, would, on account of the relatively higher elastic limit of the unannealed steel, effect a still greater saving in weight. The diminished weight of the dead load of the bridge would then be an important factor for consideration; nor would it lose in rigidity or in resistance to deformation under a load or shock, for in point of rigidity nickel-steel excels simple carbon-steel relatively as much as in tension. The value of resisting corrosion is apparent in structural steels, and it is found that nickel-steel offers an advantage over carbon-steel of from 25 per cent. to 50 per cent. less corrosion.—**R. H. Watson,** *Proc. of Engineers Soc. of Western Pennsylvania, Vol. XIX., No. 5,* pp. 273–283.—*P. L.*

An Introduction to the Study of Alloys.

Solids like ice, which result from the solidification of aqueous solutions, rocks and metals, which have resulted from the solidification of fused masses, present certain common features. The microstructure of a crystallised rock to some extent resembles that of a crystallised metal. Ingots of steel contain at the upper end a contraction cavity or "pipe," and similar cavities are often found in ingots of artificial ice. Crystals are often found in the cavities of rocks, so too crystals of iron may at times occur in the cavities of steel ingots, and minute crystals of ice in the cavities of artificial blocks of ice. Gases evolved during solidification cause gas bubbles or "blow-holes" in ingots of ice or of steel. These blow-holes form at a time when the mass is still fluid enough to be pushed aside by the particles of gas evolved within it, so that they come together to form gas bubbles; yet not fluid enough to permit these bubbles to rise by gravity to the upper surface and thus escape. Passing on to the chemical compounds of one metal with another, the author states that in general they do not follow the law of valence and are therefore of the type known as molecular. As they do not follow the law of valence these unions of one metal with another represent feeble combinations, and their properties differ from those of their component metals in a very much less degree than is the case with the common strong chemical compounds familiar to inorganic chemistry. The properties of water are wholly different from those of hydrogen and oxygen, the properties of common salt give no suggestion of those of chlorine or sodium No such striking difference is found between the properties of a definite compound of aluminium with gold on the one hand and the properties of aluminium and gold respectively on the other. These substances are termed "solid solutions," in order to distinguish them from solid definite chemical compounds. A solid solution bears the same relationship to a definite solid chemical compound that a liquid solution bears to a definite liquid chemical compound; in other words, solids which have the essential characteristics of solutions so far as solidity itself permits.—**Prof. H. M. Howe,** *Eng. Mag., Vol. XXV., No. 5,* pp. 647-656.—*P. L.*

The Restoration of Dangerously Crystalline Steel by Heat Treatment.

Dangerously crystallised steel may be divided into three classes:—(1) Occurs only in mild steel of low carbon or pure iron, and is caused by annealing for a long period at too low a temperature, and in a slightly oxidising atmosphere; (2) a type of brittleness produced by continued heating at high temperatures; (3) a type, occasionally met with, produced by heating the steel till it is practically burnt; in other words, heating so near fusion that an evolution of gas occurs in the interior of the steel, which tends to separate the crystals from each other, and by so doing destroy the continuity of the mass. Steel possessing the last type of brittleness, although greatly improved by heat treatment, can never be restored by simple heating. Brittle steels of types 1 and 2 may, by suitable heat treatment, be rendered equal or even superior to the normal or forged steel. The form of heat treatment recommended consists in heating the steel to a temperature of from 870 degs. to 900 degs. Cent., and by submitting dangerously crystallised steel to this simple heating it can be completely restored to the best possible condition without forging down to smaller size or remelting. This, whilst heating to a high temperature, causes a development in the size of the crystalline grains, making the steel brittle. Such conditions may be reversed by reheating the material to about 870 degs., resulting in the cold steel regaining its original or even better structure.—**J. E. Stead, F.R.S.,** and **A. W. Richards,** *Proc. Iron & Steel Inst., Sept., 1903.*—*P. L.*

New Applications of Alumino-thermite with Iron and Steel.

Experiments made by the author with a view to replacing the aluminium in thermite by silicon have failed to give any positive results, as the mixture, once ignited, does not go on burning spontaneously, as is the case with alumino-thermite. The uses of thermite iron as a solder are discussed at some length, this substance allowing of uniting not only rails and girders but practically any kind of wrought and rolled iron at a cost much lower than by any other method. Thermite appears to be specially useful in repairing ships; some cases being recorded where ships were able to resume their route after a very short stay, whereas, with any other process repairing the broken parts would have required a rest of several weeks for the

steamers, and necessitated very high expenses. Thermite allows of the soldering being made without any previous dismounting. If fissures are to be filled they should first be enlarged by means of mechanical tools, when the thermite iron is added. In the case of wrought iron being soldered to wrought iron, thermite iron should be used only to soften the soldering surfaces, hot liquid wrought iron having to be cast in afterwards so as to displace the thermite iron. Adding about 100 to 250 gram. pig-iron to the thermite will result in a hard, easily forgeable steel with small grains, affording a convenient means of casting repair parts.—**Dr. H. Goldschmidt** (Paper read before the 5th Congress for Applied Chemistry, Berlin); *Glückauf XXIX., No. 27*, p. 633).—*A. G.*

The Influence of Varying Casting Temperatures on the Properties of Alloys.

In this Research, presented to the Spring meeting of the Iron and Steel Institute, the author examined the influence of varying casting temperatures on the mechanical and other properties of alloys. Tensile test results and casting temperatures are given in the following table:—

Alloy.	No.	Casting Temperature. Degrees C.	Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Extension per cent. on 2".	Contraction of Area per cent.
Gun Metal	1	1173°	6·468	8·376	5·5	4·23
	2	1069°	8·482	14·838	14·5	16·71
	3	965°	8·984	11·018	5·0	6·36
Yellow Brass	4	1182°	4·432	11·484	37·75	31·405
	5	1020°	3·976	12·713	43·00	35·66
	6	850°	4·150	7·447	15·00	15·25
Red Brass	7	1308°	4·284	6·855	13·25	12·65
	8	1073°	4·263	12·649	26·00	30·285
	9	1058°	4·376	5·670	5·5	6·64
Muntz Metal	10	1038°	8·753	12·454	6·0	10·60
	11	973°	9·637	18·889	15·0	16·10
	12	943°	9·526	16·287	9·5	14·81
Cast Iron	13	"Hot"		12·271		
	14	"Fair"		13·104		
	15	"Cold"		11·094		
Malleable Iron	16	"Hot"	17·41	24·335	1·75	
	17	"Fair"	16·16	26·937	5·75	10·16
	18	"Cold"	12·24	24·02	3·50	6·24
Gun Metal	19		6·523	7·211	1·00	1·05
	20		6·556	10·069	4·00	2·42
	21		7·362	9·502	2·00	2·86

The seven alloys distinctly show, when tested mechanically, the influence of varying casting temperatures, the most noteworthy being that of the red brass alloy. The gun-metal alloy is specially interesting, as showing that in a 50-lb. crucible two minutes on either side of the fair casting heat will result in a product failing to meet the usual specifications demanded by this composition. The microscopical results throw much light on the mechanical tests. Generally the high temperature castings have a large, ill-developed type of crystallisation, conveniently described as "loose." The structures of the castings poured at the fair casting heat are characterised by the manner in which the crystals are dovetailed one into the other, conveniently described as "interlocked." The low temperature castings are marked by a well-developed or "pronounced" type of crystallisation. The crystal junctions of these castings are exceedingly sharp, and tend to form routes along which fracture readily travels.—**P. Longmuir** *(Carnegie Research Scholar), Engineering, Vol. LXXVI., No. 1963*, pp. 231–234, and *No. 1964*, pp. 263–265.—*P. L.*

Researches on Manganese Steels.

The author examines at considerable length the micrography of manganese steels, which he divides into three classes according to the table on the following page. Steels of the second series vary in constitution according to their degree of carburisation. The special constituent which replaces martensite in the more carburetted steels gives every appearance of troostite. It is shown by very slight etching, in the form of black lobes; it gives the steel the properties of a gentle quenching, and it disappears by quenching at 900 degs. C.—observations which coincide with the properties of troostite. This opinion has been confirmed by more recent

RESEARCHES ON MANGANESE STEELS.

Class.	Microstructure.	Content of Manganese.	
		Steels of the 1st series, less than 0·300 carbon.	Steels of the 2nd series, more than 0·700 carbon.
I.	Pearlite	From 0 to 5 %	From 0 to 3 %
II.	Martensite and a special constituent	From 5 to 12 %	From 3 to 7 %
III.	The polyhedral structure of γ iron ...	Over 12 %	Over 7 %

researches on chrome steels, and the author believes it necessary to remove the hypothesis of a double carbide of iron and manganese, or of a carbide of manganese other than that isolated by Hautefeuille and Troost (Mn_3C). An extensive series of mechanical tests are given, from which the following conclusions are drawn. Steels having an ordinary carbon content are improved by an addition of manganese. They have a higher tenacity, are remarkably homogeneous and possess a toughness that is only met with in special steels. Manganese steels with a martensitic structure have a very high tenacity, but are very fragile. Manganese steels of polyhedral structure are generally very hard, and hence difficult to work. The author throughout draws a striking analogy between manganese and nickel steels, and concludes his research saying, there is an absolute agreement—the results of micrographical examination and the mechanical tests.—**Léon Guillet,** *Docteur ès Sciences, Le Génie Civil, Vol. XLIII., No. 17,* pp. 261–264; *Le Génie Civil, Vol. XLIII., No. 18,* pp. 280–282.—*P. L.*

PRIME MOVERS.

Steam Turbines.

IN reply to questions relative to his paper read before the recent Engineering Conference, the author stated that the multicellular turbine in question is constructed by Messrs. Sautter-Harle & Co., of Paris, and consists of a series of rotating wheels keyed on the turbine shaft, and separated by circumferential diaphragms held in grooves inside the turbine casing. The wheels consist of buckled steel plates, conical in shape, on the periphery of which are riveted nickel steel blades, further held in place by a band. The guide blades are fitted in the periphery of the diaphragms opposite the wheels. The steam flows through the diaphragms and wheels from the inlet, its pressure decreasing progressively, each successive wheel working under a low fall in pressure. The number of wheels varies from three or four to thirty and over. All loss in efficiency through leakage between the fixed and movable parts has been prevented in a marked degree. Steam consumption is also very moderate, the difference between the calculated figures and the results obtained at trials does not generally exceed 2 per cent. From the record of trial runs made with a 500-h.p. turbine of this class for the generating station of a mine in Spain, it appears that the consumption of the turbine and dynamo at full load and 120 lbs. per sq. in. was 15·5 lbs. of steam per e.h.p.-hour, and under an overload at 640 h.p. and 156·5 lbs. per sq. in. the steam consumption was only 15 lbs. per e.h.p.-hour. The diagram shows that the total efficiency of the set, which rises to 58 per cent. at full load, remains approximately constant down to below half-load. Further, the consumption of steam—the dynamo remaining excited and being self-exciting—does not exceed 740 lbs. per hour running empty, being thus 10 per cent. lower than at full load.—**Prof. Rateau,** *Engineering, Vol. LXXVI., No. 1957, July 17, 1903,* pp. 105, 106.

Performance of an Internal Combustion Engine.

THIS paper describes a series of investigations made at the Clarkson Memorial School of Technology. The object was to determine the economic performance of a standard internal combustion engine of the Otto type using kerosene and gasoline, respectively, under otherwise similar conditions. The heating value of the two fuels, as determined by calorimetric tests, was slightly higher for the gasoline than for the kerosene. In order to use the kerosene as a power-gas in this engine it was necessary: (*a*) to atomise it by compressed air, (*b*) to vaporise the oil, (*c*) to superheat the kerosene-air mixture about 250 degs. Fahr. on the average. The kerosene gas was therefore used in a condition somewhat similar to blast-furnace and waste power-gases. The most satisfactory and economic conditions for the use of the kerosene fuel were found experimentally, by adjusting the supply of superheated kerosene-air mixture simultaneously with the regular air admission into the engine cylinder, so that the exhaust was smokeless and showed an excess of oxygen. Capacity tests were made to determine the maximum power delivered under the best operating conditions for economy and speed regulation, giving, for kerosene, a maximum of 17·41 h.p. at 309 revolutions per minute, and for gasoline, a maximum of 14·91 h.p. at 267 revolutions. The best economic loads for the engine varied with each fuel, being 8 b.h.p. for kerosene and 9·5 b.h.p. for the gasoline; that is, for kerosene at about 46 per cent. and for gasoline at about 63 per cent. of the maximum full loads for these fuels respectively. The rate of consumption was the same for each fuel at about 4·5 b.h.p. delivered. Under light loads gasoline was the more economical fuel, while kerosene proved to be the better fuel for high-duty heavy-load work. The thermal efficiency was higher for kerosene, having a maximum value of 19·2 per cent. at 9·1 b.h.p., and for gasoline a maximum of 14·9 per cent. at 9·4 b.h.p. The thermal duty reached maximum values at the above respective loads of 149,000,000 ft.-lbs. for kerosene, and of 116,200,000 ft.-lbs. for gasoline.

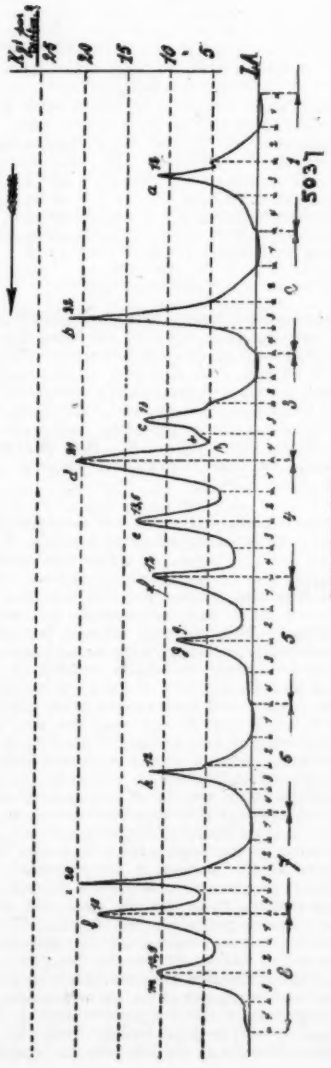
—**H. F. Halladay** and **G. O. Hodge,** *Trans. Am. Soc. Mech. E., Saratoga Mtg., Vol. XXIV., No. 0985, 1903.*

A Peculiarity of Explosion Motors.

THE writer refers to a phenomenon connected with the operation of internal combustion motors, the existence of which was discovered by means of his indicator applied to a Daimler motor. The diagrams obtained show that after certain explosions a period follows during which the pressure of gas sensibly exceeds that due to the explosion itself. The writer believes this effect to be caused by secondary combustion, and in support of his opinion he reproduces Fig. 1, and observes that the explosion *C* of 13 kilos. is followed by a compression *d* of 21 kilos. The explosion *C* is a bad explosion of small initial power, such as results from incorrect proportions of the explosive mixture or from defective ignition. To the explosion *C* of 13 kilos. corresponds a certain temperature *t*, whereas the augmented pressure of 21 kilos. corresponds with a temperature *T*. The writer cannot think that the cylinder walls are able to impart for a given period to the mixture of gases a temperature *T* greater than the maximum *t* of the period immediately preceding, and he believes that the increases of pressure can only accrue from secondary combustion. If we consider the periods *e*, *f*, *g*, which follow *d*, at the end of which the combustion is complete, all these periods correspond to the regularly and rapidly decreasing pressures and temperatures. The diagram also indicates that, if the governor acts after the strong explosion as at *i*, where the pressure of 20 kilos. is attained, the compression *b* following is not more than 18 kilos. According to his theory, the combustion was complete at *i*, and the period following merely corresponds to simple compressions and expansions without combustion, and consequently without new elements of heat.—**R. Mathot,** *La Locomotion Automobile, Vol. X, No. 29,* pp. 456–458.

The Steam Turbine from an Operating standpoint.

THE Westinghouse-Parsons turbine plant which this paper describes is the first one of its size to be put into practical operation in the United States. It is necessary to remove the top of the case of the turbine once in three months (especially when the plant is first started), as red lead or other foreign substances in the pipes are liable to clog the smaller blades, although a steam strainer is provided, which cares for any foreign substances which may in any way injure them. The turbine exhaust has supplied 25,000 sq. ft. of direct radiating surface and 7,500 sq. ft. of blower stack surface; a temperature of from 60 to 70 degs. F. was maintained in all buildings when generating 520 k.w., and with a temperature of 220 degs. F. in the exhaust chamber of the turbine. A 50-p.c. overload has been maintained at full speed for five hours without apparent injury to the machine. The turbine can be changed from condensing to non-condensing when running, this having been done daily during the heating period, and without difficulty or shut-down. The turbine costs from 10 to 15 p.c. less than the same size of reciprocating engine outfit, while the cost of the power-house is 65 p.c. less. Analysis of the results in the following table indicates that with a turbo-generator driving motors, and supplied with steam from boilers having an evaporation of



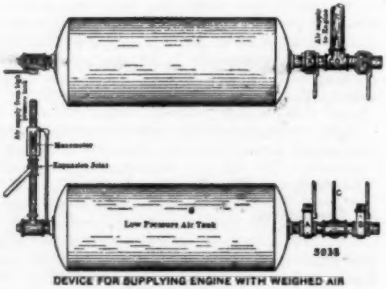
8,707 lbs. of water per lb. of coal, a brake horse-power can be delivered from the pulley of a motor for about 2½ lbs. of coal per hour. Under the same evaporative conditions the average non-condensing engines distributed through the different rooms in the plant would require 7.05 lbs. of coal for brake horse-power at the fly-wheel, or three times that of the quantity required for the electrical drive.

	150-k.w. test.	300-k.w. test.	Running Load.	400-k.w. test.	Overload Test.
Average load	152 k.w.	323 k.w.	375 k.w.	397·11 k.w.	490 k.w.
Duration of test	3 hrs.	3 hrs.	4 hrs.	3 hrs.	5 hrs.
Steam Pressure	144·85 lbs.	153·3 lbs.	152 lbs.	150·92 lbs.	152·7 lbs.
Superheat	—	3·44° F.	6·46° F.	19·66° F.	18·2° F.
Average vacuum...	27·34 ins.	27·64 ins.	27·43 ins.	26·95 ins.	27·55 ins.
Water per K.W. hour ...	28·05 lbs.	22·34 lbs.	22·29 lbs.	22·15 lbs.	21·7 lbs.
Water per E.H.P.	20·92 ,,	16·67 ,,	16·63 ,,	16·53 ,,	16·18 ,,
Water per B.H.P.	19·03 ,,	15·17 ,,	15·13 ,,	15·04 ,,	14·72 ,,
Water per I.H.P.	17·78 ,,	14·17 ,,	14·13 ,,	14·05 ,,	13·75 ,,

The author considers that the strongest appeal the turbo-generator makes to the business man or the engineer is its inherent commercial efficiency, week in and week out, year in and year out. Leaky pistons or valves, lack of alignment of slides and bearings, keying-up, and lubrication, all of which exist in the reciprocating engine, are eliminated in the turbine.—**F. A. Waldron,** *Trans. Am. Soc. Mech. E., Saratoga Mtg., Vol. XXIV., 1903.*

Testing Gas Engines.

For measuring the amount of air supplied to a 10-h.p. Otto gas engine for the purpose of some tests, the writer used an engine storage tank of about 90 cub. ft. capacity, which was filled with air compressed to 100 lbs. pressure. This air was passed through an expansion or reducing valve to a low-pressure reservoir of about 10 cub. ft. capacity, in which a pressure of about 1 in. of water was maintained. The pressure and temperatures in the tank were read before and after a test, and the weight calculated from the formula $PV = m\,RT$, in which P is the pressure in pounds per square foot, V is the volume of the tank in cubic feet, m is the weight of air in pounds, R is a constant for the gas = 53·35, and T is the temperature of the gas in Fahr. degrees measured from absolute zero. The difference in the weights before and after the test represents the amount of air consumed. Two pressure gauges were connected to the tank, one a high-pressure gauge for the start, the other a low-pressure gauge for the finish. The temperatures were obtained by five thermometers inserted at various heights on the tank. The readings of the thermometers were averaged, and the true temperature of the air ascertained. The arrangement of the low-pressure tank is shown opposite. The pipe leading from the high-pressure tank is at the left, also the expansion or reducing valve and the manometer. At the right are two quick-opening valves A and B, through one of which the air must pass in going to the engine. With B open and A closed the engine will draw air from the atmosphere, while with A open and B closed the supply will be drawn from the tank. In starting a test, the air is compressed in the storage tank, and its temperature and pressure read. At a given signal the one who operates the reducing valve allows a slight pressure to accumulate in the low-pressure tank, while another person closes B and opens A simultaneously, so that the engine continues its work without interruption but now drawing its air supply from the weighed amount. This signal is the start of the test. A thermometer in the intake pipe at C gives the temperature of the ingoing air.—**E. C. Oliver,** *Trans. Amer. Soc. Mech. E., Saratoga Mtg., Vol. XXIV., 1903.*



DEVICE FOR SUPPLYING ENGINE WITH WEIGHED AIR

TESTING GAS ENGINE.

A New Theory of Heat Power Plants *(contd.).*

Expressed algebraically, the facts of trans-power take shape in seven equations. Irreversibility is a principle second in importance only to that of the conservation of energy expressed in the First Law. The fact of irreversibility and its causes deserve to be styled the Second Law of heat-mechanics; but as the Second Law of the thermodynamic text-books is mathematically proved by assuming a physically impossible reversibility,

there may arise an awkward confusion from adopting the same title for the doctrine of irreversibility. In all cases of thermodynamic activity it is the factor H′, or heat transpower, that introduces "irreversibility." The total resilience, whose time-rate of exertion is mechanical transpower, is measured by the total mechanical work done in unstraining to the limit of complete freedom from strain. There are two means of producing resilience in material, which two may be combined in any proportions. The first is purely dynamic, and consists in adiabatic stressing, the accompanying straining being governed by the special adiabatic elastic law of the material dealt with. In any subsequent unstraining the resilience so developed is wholly recovered in work done. The second is by the operation of thermal transpower. The clearest method of following all thermodynamic actions is to analyse them into two parts, corresponding to the purely dynamic and purely thermal methods of creating and of spending resilience. The creation of resilience by mechanical work is perfectly reversible. The creation of resilience by heat transpower is irreversible. The same is true of the creation of resilience by internal heat generation. The resilience so created by heat can always be discharged mechanically by adiabatic unstraining. If the efficiency of such complete discharge were measured by the ratio of the mechanical work done during discharge to the resilience created during the charge, this efficiency would be perfect or unity. Again, if the adiabatic discharge be interfered with by thermal transpower in such manner as to lessen the work done, then another "efficiency" could be calculated as the ratio of work done down to complete freedom from stress and strain, to the full initial adiabatic resilience. Since, however, heat transpower during discharge may increase, instead of diminishing, the work done, such a measure of efficiency consistently carried out would sometimes give a measure greater than unity. This ratio is, therefore, best not called an "efficiency"; it may be called the "dynothermic coefficient." Having examined the proportion in which resilience is produced by heat transpower and generation, the writer examines the conditions under which the resilience so produced can be economically used in giving utilisable mechanical work. In internal-combustion gas engines a larger proportion of the heat resilience is created at the minimum volume, while steam has it created at gradually increasing volume during evaporation. This defeat of steam as a power medium leads to consideration of the next fundamental limiting condition imposed by industrial necessities. This is the pressure limit. The reasons against high pressure are the increased prime cost of boilers, engines, etc., and the increased difficulty in keeping joints tight. If the cost went up with the pressure by a straight-line law, then the resilience obtained per unit of cost would increase indefinitely with the pressure. The constructive difficulties, however, go on increasing in an accumulative ratio. But the problem as to most profitable initial pressure may be looked for in another way, and the history of the development of the Diesel engine followed precisely the line of argument here submitted. One element in the great practical success of steam-power plant is clearly due to the fact that steady production of steam naturally leads to evaporation at constant pressure. Another element in this success has no doubt been due to a large proportion of the heat being necessarily supplied at practically constant volume—that portion, namely, spent in heating the water to evaporation pressure. The author therefore describes the solution of the problem by graphic methods. The principle and method described enable one to calculate a rough approximation of the truth, and this appears to the author better than neglecting altogether the principle of all-round economy. In the final article is shown how speed affects the main problem of economy. **—Prof. R. H. Smith,** *The Engineer*, *Vol. XCVI., Nos. 2482-2486.*

Entropy.

THE author begins in this paper a discussion of Entropy, to explain his views more fully than was possible in his Presidential Address to the Institution of Electrical Engineers, when his few remarks on that subject gave rise to a remarkable controversy. After criticising the usual treatment of entropy in text-books, and emphasising the confusion of mind into which readers are led by inaccuracy and inconsistency on the part of writers on the steam-engine, the author explains the difficulties he himself encountered when he first tried to understand the subject from text-books, and then enters on an exposition of entropy from the point of view of the engineer, who has to deal with real, and therefore irreversible, changes. Energy is indestructible, but it may be degraded into lower forms, into heat as the lowest form; and while some of this heat may sometimes be raised again into work, that can only be done by giving out the rest of the heat at a lower temperature. The portion thus given out at the lowest available temperature is of no use—it is waste, and what the engineer is concerned about is to make this waste as small as possible. Entropy may be defined thus:—Increase of entropy is a quantity which, when multiplied by the lowest available temperature, gives the incurred waste. This incurred waste may be energy already irrevocably degraded into heat, or energy which must be degraded into heat in bringing the working substance back to the standard state. By increase of entropy is meant the increase as a whole in any isolated system or region having no exchange of energy with anything outside it during the increase. The importance of measuring waste by the product of these two factors, entropy and lowest available temperature, instead of by another quantity of the same dimensions as energy, is that the practical value of heat depends on the temperature, and the waste cannot be known until the lowest available temperature is known. The author then develops the following fundamental principles:—Energy is conservative or constant in quantity in the universe, or in any part of it which neither takes in nor gives out energy. This is the first law of thermodynamics, as it involves the equivalence of heat

and work. Waste, once incurred, cannot be diminished in the universe, or in any part of it, which neither takes in nor gives out energy. This is the second law of thermo-dynamics. The author then discusses the reversible cycle but in a somewhat original manner, and develops the equations—

$$\frac{H_1}{H_2} = \frac{\theta_1}{\theta_2}$$

where H_1 is the heat taken in by the perfect gas at temperature θ_1 and H_2 is heat given out at temperature θ_2; and

$$w = H_1 \frac{\theta_1 - \theta_2}{\theta_1}$$

where w is the balance of work done; or

$$\text{efficiency} = w / H_1 = (\theta_1 - \theta_2) / \theta_1.$$

It is also shown that this is the maximum ideal of theoretical efficiency. The first equation above gives us—

$$H_2 = H_1 \frac{\theta_2}{\theta_1},$$

which shows that the incurred waste in the conversion of work into an equivalent quantity of heat at any given temperature varies inversely as the temperature at which the heat is formed and directly as the lowest available temperature. But our definition of entropy gives us—

$$H_2 = \phi\theta_2, \text{ i.e., } \phi = H_2 / \theta_2 = H_1 / \theta_1$$

where H_1 is the heat taken in, and θ_1 the temperature of the envelope through which it passes. Thus the entropy is independent of the lowest available temperature. If, then, we know the amount of heat produced, H_1, and the temperature θ_1, we can get ϕ and we need not trouble about the ultimate actual waste. Similarly, if a change has taken place which has produced no heat, but necessitates the subsequent degradation of energy into heat to get the working substance back to its original state, we have no idea of the waste so caused, but if we know the highest temperature θ_1 at which the inevitable heat can be given out, we get $H_1 / \theta_1 = \phi$ the entropy, and that gives us the incurred waste corresponding to any lower temperature that may eventually be available. Thus, as in all real changes waste is incurred, every real change necessitates an increase of entropy. The function of the engineer is to make this increase as small as possible. — **J. Swinburne,** *Engineering, Aug. 28, 1903,* pp. 271-276.—*W.C.H.*

Experiments on the Efficiency of Non-conducting Coverings for Steam Piping.

THESE experiments were carried out in Edinburgh University with the aid of apparatus designed by Prof. Hudson-Beare, and the following observations were made in each set of tests. (1) The air temperature of the room; (2) the pressure of steam entering the pipe; (3) the pressure of air; (4) the amount of steam condensed every half-hour; and (5) the temperature of the outside of the covering. The table here reproduced gives the heat losses in B.T.U. per sq. ft. of pipe surface (measured uncovered) per hour per deg. Fahr. difference in temperature at various steam pressures, as well as the average value of these losses in each set of experiments.

HEAT LOSSES IN BRITISH THERMAL UNITS per sq. ft. of Pipe Surface (Measured Uncovered) per hour per deg. (Fahr.) Difference in Temperature.

Covering.	At Various Steam Pressures by Gauge.				Mean over all the Experiments
	25 lb.	50 lb.	70 lb.	100 lb.	
Uncovered pipe ...	2·20	2·95	3·20	3·20	2·89
Slag wool ...	0·52	0·58	0·62	0·66	0·595
Hair and felt	0·49	0·59	0·58	0·58	0·56
Felt	0·70	0·76	0·79	0·79	0·76
Magnesia ...	0·50	0·56	0·59	0·60	0·563

From these figures the great saving which can be effected by using any of these coverings is demonstrated, the condensation in the uncovered pipe being from 4 to 5½ times greater than in a covered pipe. — **W. N. Bolam** and **T. Grieve,** *Engineering, Vol. LXXVI., No. 1962, Aug. 7, 1903,* pp. 171-172.

TRACTION.

Relation of Speed to Curvature.

WITH the general increase in the sustained speed of passenger trains there is a growing tendency to recognise established limits of speed in relation to curvature. It is well understood that the elevation applied to any curve is the theoretical equivalent of only one speed, but wide variations from the same either way are practicable. For this reason it is seldom the case that curves are elevated fully for the highest speeds, the exceptions being usually where the freight traffic is light, or where the track is used exclusively for passenger traffic; but even where the conditions are such that the preference may be given to the passenger traffic sharp curves are not elevated to anything like the theoretical requirements for high speed. The logical view of the situation has always been that speed should be reduced on sharp curves to a rate which holds a reasonable relation with the elevation. The fact that engineers often run at a higher speed than is considered safe in this connection shows that mathematical rules regarding curve elevation are not rigorously regarded. Nevertheless it is widely considered that engineers may indulge in reckless running on even ordinary curves, and that limits of speed in relation to curvature should be observed that are quite within frequent excesses in this respect. A practical recognition of this principle is the fact that reduction of curvature is one of the leading features of railway improvements at the present time. It appears that the opinions of English railway men are quite as conservative regarding fast speed on curves as the rules laid down by the committee of the Mainte-

nance of Way Association in 1901.—*Rail. & Eng. Rev. (Edit.), July 25th, 1903*, pp. 572, 573.—*C. S. L.*

Petrol Motors for Locomotion.

THE desirable qualities in engines for road locomotion are lightness, simplicity, absence of excessive vibration and noise, durability and economy of fuel. Lightness requires quick-running engines; speeds of 1,500 revolutions per minute have been used, but for good working and durability, it is advisable not to exceed 800 revolutions per minute. Weight is reduced by the use of special steel for the working parts, and of aluminium for the casings. For simplicity, automatic admission valves are largely used, but a tendency exists to revert to mechanical operation for both valves, especially in very quick-running engines. Absence of vibration and regularity of motion are obtained by the use of several cylinders. Balancing is sometimes effected by the use of two pistons in one cylinder, moving in opposite directions. For economy of fuel it is important to mix the fuel and air in precise proportions. Many carburators can be regulated at will to admit a supplementary quantity of air, but this regulation is made at a guess. The Krebs carburator is designed to give the exact proportions of air and fuel at any speed of the motor. Effective water-circulation is a necessity, except for very small engines, which may be air-cooled. For cooling the water, the ordinary radiating coil, consisting of a pipe with outside projections, seems more reliable than the bee-hive radiator, which is more subject to leakage. In recent construction a fan is often used to blow air on to the radiator when the carriage is standing. This fan ought not to interfere with the current of air resulting from the speed of the motor-car. Excessive cooling is detrimental to the economic working of the motor, but some experiments show that it increases the power.—**E. Sauvage,** *Proc. Inst. C.E., Vol. CLIV., Sec. III.*

Report on Mr. Young's Return Relating to Permanent Ways.

IN Great Britain and Ireland, the girder rail is the only rail in use on public streets, and the greater number of systems adopt a rail weighing between 90 and 100 lbs. per yd. Almost 50 per cent. of the systems have a rail 7 ins. deep, a considerable number having 6½ and 6 ins., and out of every three tramway systems, two use rails with a flat head and one has the head coned. The width of the groove on straight track rails varies from 1 in. to 1¼ in., but 1⅛ in. and 1 in. are the most common. About 35 per cent. of the tramways reporting use a specially high guard lip on the curve, of which the maximum height seems to be ⅝ in. above the tread. Several systems use check rails on the sharper curves. The returns show that at the present time 40 per cent. of the systems use 45 ft. rails. There is considerable variation in the gauges adopted. The most common is the railway gauge of 4 ft. 8½ ins., but several systems have a 4-ft. 0-in. gauge, and about twenty use a 3-ft. 6-in. gauge. The chemical composition specified by the different engineers shows that a considerable difference of opinion exists as to what is required. The average carbon, in the majority of cases, seems to be about ·53 per cent. Regarding the rail in its capacity as an electrical conductor, the percentage of manganese wished for in most cases appears to be about 90 per cent. In several cases a high silicon is specified with a very high carbon, which, if obtained, would necessitate a careful handling of the rails. Generally, the tendency is to specify a higher carbon rail than was formerly used. After the rail itself, there is no more important problem than the method to be adopted in joining these into a continuous, smooth-running road. In this connection, mention must be made of the chemical welding material "thermit," lately put on the market. At least eight towns are at present experimenting with this device. At Leeds the trials have been extensive. In Glasgow we purpose making a trial of several hundred joints. Returns for cast weld-joints are curiously at variance. The present practice regarding the bonding of welded joints is to put no bonds with chemical or electrical welds. With cast welds, about 50 per cent. of the towns seem to bond in addition. Apart from the question of joints, but to a certain extent connected with it, is the fixing down of the rails to the bed, not only at their ends, but at intervals in the length. The tendency seems to be to adopt this more largely in the future. Of the total systems reporting, two out of every three have the joints placed opposite each other. At the same time, the experience of some of the earlier systems has led them to adopt "staggered" joints. The tendency is clearly to go in for longer points and tongues than in the past. Obvious benefits are derived from a long tongue, especially if curved on the branch-off side. There is considerable diversity of opinion as to whether tongues should be placed on the inside or outside of curves, and as to the advantage of having two movable tongues instead of one tongue and a dumb point. The replies regarding the use of hardened steel renewable centre-pieces are remarkably unanimous. Twenty towns are pronouncedly in favour: two consider them unsatisfactory, the others have not had sufficient experience to express an opinion. About twenty-one towns have in use special work of manganese steel. In most cases the work seems to have been lately laid down, and no opinion is expressed as to its merits. In laying a new track where a new concrete bed is required, the replies show that engineers are divided almost exactly equally between two methods. The majority of the systems reporting pave the two tracks with granite setts, wood being next in favour, and then basaltic setts. From a limited experience of wood paving in Glasgow, the writer is of opinion that the nature of the grouting of the joints has a considerable influence on the success or failure of wood paving. In about a dozen towns widening of the gauge has resulted from the expansion of the wood paving. The testimony against the use of asphalte between and alongside the rails is very strong. Many

towns experience trouble from the paving setts or blocks rising alongside the rails. "Rutting" of the paving by heavy traffic seeking the rails is a source of expense in towns. About a dozen systems use cast-iron blocks, chilled on the surface, and laid alongside the rails to mitigate this wear. The construction of the duct or cable track is a matter of great importance and interest, and more information on this subject would be of value Earthenware ducts or pipes are used on 65 per cent. of the systems reported on. Almost all these lay the ducts solid in concrete. The spacing of manholes varies remarkably on different systems, the average distance being about 100 yds. The replies show that in no case has any chemical action on the cables from the material of the duct track been found. Cross bonding of the track is almost universal. The usual distance apart of the bonds is 40 lineal yds. On very few systems does it seem possible to estimate the wear due to electric traction. It is also useless to attempt any summary of the annual cost per mile of track for maintenance. The general indication is that the greater part of the cost of maintenance in most towns is expended on the paving. In considering the question of curves, it is interesting to note that there is very little variation in the lengths of the single-truck car wheel-bases. The grades in streets where it is imperative to have a tramway are frequently very severe. The returns show that 65 per cent. of the tramways sand both rails on gradients, while the remainder sand one rail only. A mechanical track cleaner is used on several systems, but its success seems doubtful. Eight towns make provision for obviating a stoppage of the car-traffic when the hose of the Fire Brigade is laid across the car lines.—**Chas. A. King,** *Tramway and Rly. Wld., Vol XIV., No. 11, Aug., 1903,* pp. 136-140.

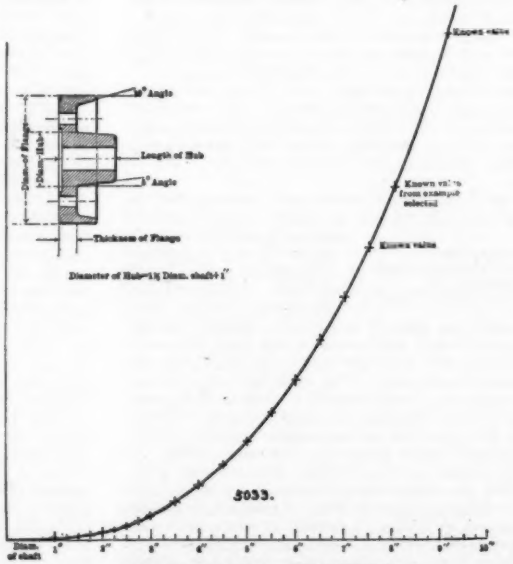
MECHANICAL.

Dimensions for Flanged Shaft Couplings.

THE total sectional area of bolts multiplied by the distance from centre of bolt to centre of shaft gives a correct measure of the strength of the bolting. This product was calculated for couplings for shafts of 8 ins. diam. and larger, and the values were plotted in connection with the diameter of the corresponding shafts. The curve traced through the average positions is shown in the diagram. The curve looked like a parabola, and trials at two or three points gave $x = \cdot 529\, d^{2\cdot 7}$ as a very close approximation. The diameter of hub of coupling was obtained by deriving a simple formula. Putting h for the diameter of hub and d for diameter of shaft, a formula of the type of $h = ad + b$ was tried. The value of a was found to be 1¾, and of b, 1 in. This equation gave a satisfactory result. The bolt circles can be selected for each coupling by assuming a suitable diameter of bolt, and the division of the value of x by the radius of the bolt circle gave the number of sq. ins. of bolt area required. The number of bolts being assumed, the area, and therefore the diameter, of each one can be easily obtained. The remaining dimensions of the couplings follow easily from those already fixed.—**S. H. Bunnell,** *Amer Machst., Vol. XXVI., No. 29,* pp. 1014–1015.

Speeds of Cranes and Economic Handling of Material.

THE proper speeds for a crane depend upon the purpose for which it is intended. The ideal condition is rapid acceleration, uniform motion at a high speed, and quick slowing down. Rapid acceleration can be obtained by employing series-wound motors, if permanently coupled, or the inertia of a continuously running motor if working through clutches. Quick stopping is effectively achieved by an electric brake working on the armature-shaft, operated by a weight or spring, and taken off by a solenoid in series with the motor. Such a brake is of almost universal application to the hoisting motor, and serves not only to prevent the load accidentally running down, but to stop the motor quickly, giving to the motor the exactitude and precision characteristic of hydraulic cranes. Most cranes are fitted with an additional mechanical brake which prevents the load descend-



BASE CURVE FOR SHAFT COUPLING DIMENSIONS.

DIMENSIONS FOR FLANGED SHAFT COUPLINGS.

ing fast enough to drive the motor. The author deals seriatim with the different designs of cranes, including fixed jib-cranes, fixed rotary-cranes, overhead travelling cranes, gantry and cantilever cranes, and locomotive steam-cranes. The following table is given in the appendix.—**A. P. Head,** *Proc. Inst. C.E., Vol. CLIV., Sec. III., 1903.*

SPEEDS OF ELECTRIC OVERHEAD TRAVELLING CRANES.—(SUNDRY ENGLISH MAKES.)

Lifting Capacity.	Speed with Full Load in Feet per Minute.				
	Hoisting.			Cross-Traversing.	Longitudinal Travelling.
	Main.		Auxiliary.		
Tons.	Ft.	Ins.	Feet.	Feet.	Feet.
100	3	6	14	50	80
100	2	0	7	50	60
50	6	0	24	70	125
50	3	0	30	40	80
40	3	0	—	50	80
20	10	0	40	100	200
10	10	0	—	60	150
5	20	0	—	60	150
3	30	0	—	60	150
3	30	0	—	100	325

Design for a Circle or Arc Slide-rest.

IN this tool the hand-wheel, acting through a worm and worm-gear, carries the right-angle slides by means of a stud working in the right-angle slots. The stud, with its slide-block, is set by means of a screw and scale on one of the castings, so that the circle or arc desired can easily be found. One illustration given by the writer shows how a tool is used for inside curves common to mould and forming die work, the radius of the cutting tool being deducted on the scale from the circle to be turned. An extra post-holder is sometimes used for getting at work between the lathe centres, the extra holder being fixed on the slide-rest. Another cut illustrates its use as a circular cutter grinder, the movement of the worm-wheel carrying the stud being communicated to the cutter or grinder in the tool-post. This cutter can be changed in position without affecting the circle determined by the stud, which can be moved to accommodate removal of stock before setting to size required. The slide-rest being held in the engine-lathe tool-post block, admits of all-around adjustment in approaching the arc to be turned on any quadrant.—**F. J. Le Card,** *Amer. Machst., Vol. XXVI., No. 23,* p. 794.

APPLIED ELECTRICITY.

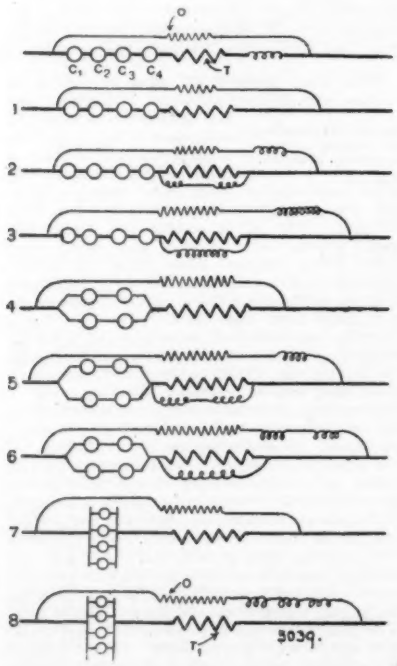
External Conductivity of Silver Wires Immersed in Water.

THE experiments described in this note present some interest for the manufacture of rheostats made up of metallic wires immersed in a liquid. The author terms "external conductivity" of a body the quantity of heat passing through 1 cm² surface during a second, the difference between the temperature of the surface of this body and that of the surrounding medium being 1 deg. Cent. The determination of this conductivity between silver and water is the subject of this paper. Silver wires from 0·281 mm. to 0·868 mm. in diameter, soldered to cylindrical brass electrodes, are placed inside of glass tubes traversed by a continuous current of distilled water, these wires being traversed by electric currents, the intensity of which was measured by means of a standardised galvanometer. At the same time the p.d. of two points of the wire would be determined by comparing it with the e.m.f. of a Clark element. The resistance of the wires and the amount of heat developed by the current could hence be determined, a stationary state being arrived at; this amount is equal to that passing through the external surface of the wire. From these experiments it is inferred that the external conductivity is practically proportional to the square root of the speed of the watercurrent.—**E. Rogoosky,** *Comptes Rendus, Vol. CXXXVI.,* 1903, pp. 1391–1393.—*A. G.*

Speed Regulation of Continuous-Current Motors.

THE latest method of speed regulation in traction work is that introduced by Lundell. In this system the principle of series-paralleling from two armature circuits to four, is combined with the series and shunt methods of excitation, together with the Sprague method of varying the field strength. The whole combination gives complete control over current and speed over wide limits, relying solely upon the ohmic resistance and counter e.m.f.'s of the machines, external resistances in the armature circuits being completely done away with. This is brought about by furnishing each motor with two armature windings, two commutators, and a field magnet so constructed that it will be possible to run with a weak field without excessive sparking. Fig. 1 shows a diagram of the various circuit combinations for two railway motors constructed on the above principles. *O* represents the shunt windings, *T* the series windings, C^1 C^2 commutators for one motor, C^3 C^4 commutators for the other motor. As it is possible to obtain a varying field strength, each armature combination, excepting the parallel one, yields three different speeds. The first three combinations (first, second, and third) give 125 volts per commutator (with 500 volts on line), the motors working practically as shunt motors, owing to the very strong shunt and the weak series field. The next three speeds (fourth, fifth, and sixth) give 250 volts per commutator. The series fields have become stronger, and at the seventh position are four times as strong as at the first position.

At the eighth position they are further strengthened by an increase in the current flowing through the armatures. When top speed is reached the motors are practically working as series motors, seeing the shunt field has been greatly reduced owing to the insertion of additional resistance in series with it. It will be seen that the speed of the motors depends upon their counter e.m.f.'s, which in turn depend upon the grouping of the armature windings and the field strength. This system has the following advantages: When the speed of the motors exceeds the speeds corresponding to a certain position of the controller, by reason of the car running down hill, the motors will become dynamos and restore energy to the line. Secondly, when any series-parallel changes are effected, the number of watts to be broken at the controller contacts is very small, being equal to the difference between the line voltage and the counter e.m.f. multiplied by the main current flowing at the time, or watts = (impressed e.m.f. − counter e.m.f.) $\times C$. The great advantages which this system has over the older methods of speed regulation in traction work brings one to the conclusion that, although not impossible, it will be very difficult to improve upon it.—**W. Rogers,** *Elec. Eng., Vol. XXXII., No. 5,* pp. 231-233.



SPEED REGULATION.

THE author discusses the advantages attendant on the use of electromotors, as compared with other power-machines. After pointing to their facilities of installation, he draws attention to the possibility of diminishing the wear and tear by a convenient automatical lubrication of the bearings. As with all the later types of electromotors the collector is fitted with carbon brushes, any sparking may easily be avoided. The number of revolutions of the motors is susceptible of being varied at will, so as to allow of direct coupling being used, avoiding the waste of energy inherent to the use of transmissions. Moreover, electromotors will work with the same efficiency at practically any load, the consumption of energy being nearly proportional to the latter. Electromotors are a valuable source of profit to electricity works, enabling the latter to maintain more constant loads. The author finally records some practical figures, illustrating the above.—**A. Lowit,** *Der Elektrot., Vol. XXII., No. 6, July 31, 1903,* pp. 124-126.—*A. G.*

Use of Electromotors in Small Industries.

THE author of this paper reviews at some length the methods available for applying electrical power in various industries, commencing with those of general character, then considering how they may be realised in particular cases with the maximum advantage. Various questions present themselves in connection with the study of the electrical transmission of power to which immediate answers cannot be made. Among these are (1) the degree to which subdivision of the total power should be carried, (2) the extent to which mechanical transmission should be continued concurrently with electrical transmission, (3) the types of motors and generators for adoption, and (4) the systems of distribution and voltages to be adopted. These questions are examined successively, and this examination, although leading to no universally applicable conclusions, which are naturally impossible owing to the diverse conditions of various industries, will serve to demonstrate general principles which may be useful for the guidance of the engineer.—**M. E. de Marchena,** *Mem. Soc. Ing. Civ. (France), 6e Serie, No. 5,* pp. 707-765.

Industrial Applications of Electrical Power.

THE author draws attention to the fact that the Swedish chemist Dr. Jungner before Edison, it appears, recognised the excellent depolarising properties shown by nickel oxide, provided this substance be fixed on a convenient supporting mass. On account of the serious drawbacks inherent in lead accumulators, as used for transportation purposes, Mr. Schoop has made a thorough comparative study of both of the above forms of storage batteries, the main results arrived at being as follows:—Nickel sheets in caustic liquids when exposed to the action of the electric current will undergo no corrosive action, as observed in the case of the lead accumulator. A possible disaggregation of

The Edison-Jungner Accumulator.

the active mass should, however, be carefully cautioned against. A possible diminution in the capacity could, in the author's opinion, easily be avoided by glowing the active plates. On the whole, there appear to be beside the undoubted advantages, some rather material drawbacks as well, to the use of the Jungner-Edison accumulator in its present form, which, however, might be eliminated later on.—**M. U. Schoop** (*Elektr. Zeitschr., No. 32, Aug 6, 1903,* pp. 619–623).—*A. G.*

The use of Electrolysis in the Industry of Inorganic Products.

THE author first deals with the fundamental differences in the constitution of theoretical and practical electro-chemistry, general considerations being made as to the reasons responsible for the present state of technical chemistry. Real available processes, it is pointed out, have scarcely been designed of late years. The author then discusses some special branches of electro-chemistry. As regards metalloids, hydrogen, oxygen and bromine are, besides chlorine, of special importance, the uses of hydrogen being discussed at some length. Bromine, it is stated, is satisfactorily being recovered according to the Wünsche process in Westeregeln. The author next discusses electro-metallurgy and more especially the industry of aluminium as well as the refinery of copper and nickel. The latter, the author states, has increased to an enormous extent of late years. As compared with refinery, the direct recovery of metals by electro-chemical means has been little developed in Germany, though much work and money have been spent for similar purposes. In fact no process allowing of copper and tin being recovered direct from their ores on a commercial scale, has so far been forthcoming. The only processes of some importance in electro-chemistry are aluminium and sodium processes, apart from the recovery of gold by the Siemens and Halske method. In the second part of this paper the author proceeds to discuss the industry of chlorides, a brief account being given of their history as well as of the use of hydraulic power and of some special factories. In connection herewith the importance of the electrolysis of alkali chlorides for the recovery of alkalis and soda are pointed out, three types of the mercury diaphragm and bell processes respectively being compared with one another. In the author's opinion the greater part of the consumption of the world is supplied by the diaphragm process, the bell process having so far been little applied on account of its late origin. Mr. Brandeis finally points to the introduction of anodical oxydation into the manufacture of permanganates and the regeneration of potassium bichromate from the chrome refuses of colour manufacturies as well as electrolytical bleaching methods—**R. Brandeis,** *Paper read before the 5th Intern. Congress for Applied Chemistry;* **Zeitschr. f. Elektroch.** *Vol. IX., No. 32,* pp. 635–636).—*A. G.*

Electrolysis by Alternate Currents.

THESE experiments were suggested by a statement contained in Richards and Röpper's "Patent Letters," to the effect that by alternate current electrolysis of a thiosulphate solution between cadmium electrodes, cadmium sulphide could be prepared with satisfactory results. The first current impulse, it was presumed, would give rise to *Cd S* being formed at the electrode, the hydrogen formed by the next impulse replacing the sulphide from the electrode by causing it to fall down. Now the authors found that with alternate currents of 1,000 periods per minute and a current density as high as 4·6 amp. per square decimeter, no output worth speaking of was obtained, whereas for lower periods the output was found to increase, reaching values as high as 75 per cent. for one alternation per minute, provided the solution be well stirred. From these experiments it may be inferred that cadmium sulphide undergoes a cathodical reduction, the output obtained for lower frequencies being due only to the fact that the sulphide by stirring is removed from the electrode, its reduction thus being made impossible. Some similar experiments on other metals were made, and other possible explanations suggested.—**M. Le Blanc** *and* **K. Schick,** *Zeitschr. f. Elektrochem., Vol. IX., No. 32,* pp. 636–641.—*A. G.*

Railway and Lighting Storage Battery at Milwaukee.

THE Milwaukee Electric Lighting and Railway Company has just completed the installation of a large storage battery-plant at its central power-station, which is notable as being the first large storage battery installation in America, installed for use on either lighting or railway circuits. The use of the same batteries for railway or lighting involves a little more complication in switching, but affords a reserve for either railway or lighting plants. These advantages have already been

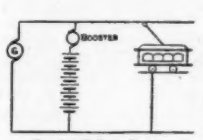


FIG 1.—Railway Battery

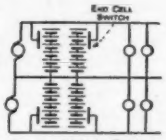


FIG 2.—Lighting Battery

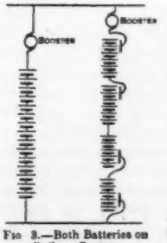


FIG 3.—Both Batteries on Railway System

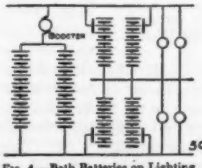


FIG 4.—Both Batteries on Lighting System

RAILWAY AND LIGHTING STORAGE BATTERY.

demonstrated at Milwaukee, as there have been times when the ability to work the entire battery on the railway load has helped the transportation department out of a very tight place. This battery consists in all of 608 cells grouped in various combinations, according to the uses to which they are being put. The railway battery consists of 288 cells connected across the railway 'bus bars in series with a special booster, as seen in Fig. 1. The battery ordinarily placed on the lighting load has its connections indicated in Fig. 2. In this battery there are 320 cells, divided into two series of 160 cells each. They are connected across the continuous-current three-wire incandescent lighting 'bus bars. An end-ce l switch, by which some of the end cells can be thrown in or out, is placed in each series of cells. In case it is desired to connect both batteries to the railway load, switches are provided by which the arrangement shown in Fig. 3 can be obtained. Here the railway battery is connected between the railway 'bus bars, just as in Fig. 1. The cells comprising the lighting battery have all been placed in series and are connected through a second booster across the railway 'bus bars. The voltage of the lighting battery is raised or lowered to correspond to that of the railway 'bus bars by cutting in or out end cells with the end-cell switches. In case both railway and lighting batteries are to be connected on the lighting circuit the arrangement shown in Fig. 4 is adopted. Here the lighting battery is connected, as in Fig. 2, and the railway battery has been divided into two sets, which are put in multiple with each other. These two sets charge or discharge on the lighting bars through the booster. The arrangement is thus very flexible. The railway battery can be charged on the lighting 'bus bars when the lighting generators would be otherwise idle, and can be put on to the railway load to help in summer traffic. In other words, the lighting generators can be made to help the railway generators without interfering with their usefulness on the lighting load. On the other hand, the railway generators might be made to help out the lighting load by charging batteries for use on the lighting circuits. The batteries act as a reserve, to tide over emergencies in either railway or lighting departments.—*Street Rly. Jnl., Rept. Electrician, Vol. LI., No. 18*, pp. 734—5.

Arc Lamps for Street Lighting.

THE writer's experience at Cincinnati during the past year has established the following facts: (1) The open-base inner globe is safer and more economical than the closed-base globe. (2) The large metal reflector is not necessary on 4-amp. series alternating-current lamps hung only 12 or 15 ft. above the street, but a small enamel reflector immediately above the arc is beneficial. (3) The initial or natural power factor of a 4-amp. series alternating current system should not be depended upon to be greater than 75 per cent., varying between 70 and 75 per cent. (4) The 75-per-cent. power factor applies to ordinary overhead circuits. When the current is supplied underground in lead-covered cables, the capacity of such cables introduces leading currents, hence the operating power factor of the underground circuits at Cincinnati is maintained above 90 per cent. (5) The efficiency can be maintained above 91 per cent., and the regulation still be perfect. (6) Four amperes is the lowest practical limit at which successful alternating-current arc lighting can be practised. (7) Carbons ½-in. diameter are the most practical size to use in a 4-amp. alternating-current lamp. (8) Notwithstanding the large size of the carbon (considering the low-energy arc), the regulation of the system is perfect, and there are no objectionable shadows from the carbons. (9) It requires only eight trimmers to take care of 4,500 lamps (10) The outages or lamps requiring starting in the underground district are less than 0·25 per cent., and in the overhead district the outages average 1 per cent.—**J. H. Halberg,** *Nat. Elec. Lt. Assoc. 26th Convention, Chicago, 1903.*

LIGHTING, HEATING, AND VENTILATION.

Ventilation of Factories and Workshops.

IN this Report the Committee deals with a portion only of the question. It is mainly concerned in prescribing a standard of sufficient ventilation for factories and workshops, based upon the proportion of CO_2 in the air. It was necessary at the outset to determine whether it was practicable to make use of this proportion as a legal standard of "sufficient" ventilation, or whether such estimations, if made with the requisite accuracy, might not prove to be both expensive and troublesome. Determinations of atmospheric carbonic acid are mainly carried out by absorption of the carbonic acid contained in a known volume of the air by a suitable alkaline solution, the amount so absorbed being ascertained by volumetric analysis. With proper precautions this process is capable of a very high degree of accuracy. The apparatus needed is somewhat bulky, but when it is merely necessary to deter mine whether the air contains an excess of carbonic acid over the quantity that could reasonably be prescribed as an official limit, vessels holding a couple of litres suffice for most purposes. The Committee recommends that the limit of carbonic acid should be fixed at 12 vols. of CO_2 per 10,000 vols. of air; and that when gas or oil is used for lighting, the proportion should not exceed 20 vols. after dark or before the first hour after daylight, the only exception to this rule to be in cases where the extra CO_2 is produced in other ways than by respiration or combustion, as in breweries. It is further recommended that arrangements be made by the Factory Department of the Home Office for the analysis of samples of air collected by inspectors, and that any analysis on which a

prosecution depends should have been performed by such qualified person or persons; and also that arrangements should be made for inspectors of factories to have the use of a properly tested portable apparatus for estimating on the spot the proportion of carbonic acid in air. Whether experiments of this kind should be entrusted to those factory inspectors who have had no training in physical science is, perhaps, open to question. One possible source of considerable error was indicated during the experiments. After standing several days the potash solution used in the apparatus was found to be coloured yellow, doubtless from the action of the alkali upon the rubber tubing of the apparatus. Any sulphur thus dissolved would form alkaline sulphides, which would absorb oxygen from the air under experiment and so vitiate the result. As a matter of fact, the figures given when the apparatus was in this condition were wholly untrustworthy.—*First Report of Departmental Committee Rev., Nature, Vol. LXVIII., No. 1763*, pp. 346–7.

Testing Heating Plants.

In practically every case when a heating apparatus is erected a certain rise in temperature is guaranteed or forms the basis of the order, and in the majority of instances this rise is from 32 degs. to 60 degs. Fahr. Occasionally the figures vary, though not to a great extent. On the completion of the work some sort of test takes place to show that the promised results are obtainable, and it is in this that a great difficulty arises. It is a very remote chance that the appointment to test finds the outdoor air at 32 degs. Fahr., and failing some recognised rule or table, the test might amount either to nothing or to a dispute. The purpose of this paper is to propose a table that might be worked to with some degree of certainty and satisfaction when the outer air is above 32 degs. Fahr. The author describes some experiments, in which each room had a normal area of glass, and each had a chimney of equal area and height acting as extract ventilating shafts. Every effort was made to get reliable normal results. On this account the temperatures on many days were discarded, or not taken, owing to something happening likely to give abnormal results. The thermometers were carefully tested, and all were hung in mid-air in positions where it was considered they would register the general temperature and not that of currents of air. From the temperatures a table of equivalent temperatures, to enable heating works to be tested when the temperature of the outer air was higher than that given in the contract or guarantee, was compiled, and is included in the paper. —**F. Dye,** *Proc. Inst. of Htg. and Ventg. Eng., June, 1903.*

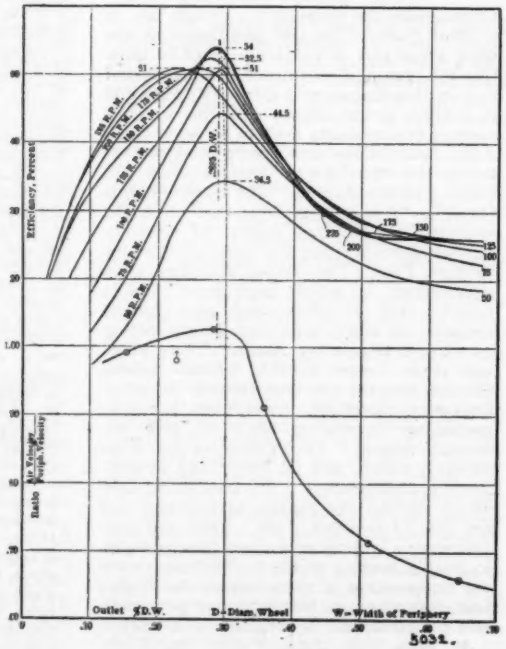
Modern Heating, Lighting and Power Gas.

After pointing out the advantages inherent in the use of gas, the author proceeds to discuss the various kinds. Generator gas is rather impure carbon monoxide with additions of carbon dioxide, oxygen and nitrogen (from the atmosphere), and water vapour, the heating value being as low as 830 to 1,000 units, corresponding with about 66 p.c. of the units of heat contained in the coal. About 1½ p.c. is lost by radiation, &c., whereas 29 p.c. are necessitated by the formation of the gas, as evidenced by the high temperature of the latter. Blast-furnace gas, as shown by analysis, is nothing short of generator gas, its most important use being in connection with gas-motors, where it has given every satisfaction. The high temperature of similar gas may be utilised only in the case of its being used for heating purposes, or by converting part of it into chemical energy (water-generator or power-gases on the one hand and water-gas on the other). A drawback in connection with water-gas is its toxicity; as it burns with a non-luminous flame, it has to be *carburetted* in the case of open flames being used. Water-gas works should be established in connection with lighting-gas works, low-grade lighting gases being improved by the addition of slightly carburetted water-gas. A most valuable property of water-gas is its high combustion temperature, enabling it to be used to advantage in smelting, soldering, brazing, as well as in glass and ceramic factories, Auer mantles being brought by it to stronger incandescence than by lighting gas. For power purposes, however, water-generator (or Dowson-) gas is mostly used, pressure and suction gases being distinguished according to the process of generating. Suction-gas plants are of late years being employed on an ever-increasing scale, as such gas allows of gas reservoirs and boilers being dispensed with, apart from higher efficiencies being obtained. The gas is first generated by means of a hand-driven fan, the motor subsequently aspiring the air mixed with water vapour through the generator. The utilisation of low-grade fuels in power-plants has of late years been rendered possible by leading the tar-like components and heavy hydro-carbons through a glowing layer of material devoid of gas and gasifying them in this way. As regards distillation gases, coke-furnace gases are being employed directly in gas-motors at Seraing with satisfactory results, and for lighting purposes in the Halifax Solway Works. Wood-gas plants have been installed in France, the gas having a heating value as high as 3,000 units. Aërogen or air-gas, *i.e.*, carburetted air, is being used both for lighting and heating purposes, but seldom in connection with power plants. As finally regards acetylene, 50 central and about 18,000 individual plants are being operated by it in Germany, the carbide consumption having been about 20,000 tons in 1902. Though the cost is about double that of charcoal incandescent-gas light, the heating effects of acetylene are less considerable and the hygienic advantages attendant on its use very high. Seven thousand tons of carbide were used in 1902 to produce the acetylene

mixture gas used to light railway cars in Germany.—**Dr. Thomae,** *Zeitschr. Ver. Deutsch. Ingen. Vol. XLVII, No. 33, August 15th, 1903,* pp. 1189-1190.—*A.G.*

Tests of a direct-connected 8-ft. Fan and Engine.

In order to secure some data for guidance the author made a series of experiments on the efficiency of a fan, with a wheel of 8 ft. diam., 37 ins. wide at the periphery and with one side inlet, the fan being driven by a direct-connected steam-engine. The pressure, volume, indicated horse-power, and efficiency have been plotted on two sets of curves. In one the abscissæ represent revolutions of fan, while each curve represents a certain size of outlet; and in the other, these two items have been interchanged, and each pressure curve has a different zero line. A number of interesting facts stand forth very clearly upon an examination of these curves. Up to a certain point the volume curves are very nearly straight, but at the higher speeds they seem to fall off. This falling off was more marked with the large openings, as was also a large increase of the vacuum at inlet. This loss in the volume delivered is unquestionably due to the throttling of air at inlet. The maximum efficiency of the combined unit was secured at 142 revs. per min., when the pressure was ½ oz. The curves show very clearly that in the selection of fans we should choose large sizes running at moderate speeds and developing low pressures. We may apparently run the same fan at a lower speed and lower pressure, so that it will deliver the same volume of air with a considerable saving in horse-power. This should be done, if in any case the conditions prevent the selection of a larger fan, but the larger fan will do the work more efficiently. In the figure are reproduced the efficiency curves and another curve showing the relation existing between the size of outlet and the ratio of air velocity to peripheral velocity of wheel. The author says, that although it is not safe to reason too much from the concrete to the abstract, he thinks the curve of the tests may be applied to different sizes of fans with reasonably satisfactory results. The paper concludes with a table recording the numerical results of the tests.—**E. S. Farwell,** *Trans. Am. Soc. M.E., Vol. XXIV., Saratoga Mtg., No. 0988.*



TESTS OF FAN AND ENGINE.

WORKS MANAGEMENT.

Modern Pattern Shop Practice.

Many pattern-makers are incapable of fastening letters or numbers on patterns, so that they will stay there. The letters or numbers should first be pierced with an awl. If the pattern surface is round a light blow with a hammer on two blocks of wood, one convex and the other concave, of the required shape, bends the letters to conform to the pattern. The letters or numbers, and the places where they go, should each have three coats of shellac. Before the last coat is dry drop each letter in place, press it down lightly, and after ten minutes drive in the needle points. In making patterns everything must be either glued or screwed. All screw heads are sunk below the surface, and the screw holes are plugged with wood plugs. All core prints should be made interchangeable. The hole bored in either pattern or core-box to locate a print should always be of the same size—say ⅜ in. If a hole is to be cored out only ½ in. it should still be located on the pattern or core-box with a ⅜-in. hole, or if the print is 5 in. in diameter it should have the ⅜-in. pin just the same; only the latter should be screwed fast with a couple of screws. All taper prints should have a standard bevel for all cope prints. All bosses should be interchangeable, having a standard size of hole. Thick glue should be used, and in all cases there should be a warming-box in a convenient place with a coil of steam pipes in the bottom and a hinged cover. If two pieces are to be glued, only one should be heated, and the glue should be put

on the cold piece. In gluing up segments they should be held together with dogs after fitting, and placed in the warming-box and heated before g uing to the ring already on the face-plate, or also in gluing end-grain pieces of core-boxes to each other. In gluing up large rings or segments a very handy rig is an iron plate with about a 3½-in. hole in the centre, which can be placed on the floor or bench. A piece of wood turned on one end to fit the hole in the plate and the hole in the face-plate on the other, and cut off to the required height, gives the pattern-maker the advantage of standing at his bench, with all his tools convenient to hand, and his work can be turned round at will.—**C. Neil,** *Amer. Machst., Vol. XXVI., No. 29,* pp. 1011, 1012.

A Remodeled Piece-Work System.

ONE of the advantages to be derived from this system is that it uses condensed forms and does not turn the mechanics and foreman into clerks. The first step is to give each machine that is manufactured a distinct symbol. The next step is to separate each machine into divisions. Then the different parts should be numbered consecutively. The pattern number and piece number should be the same and should be numbered in the drafting-room, together with the symbol. We are now ready to start a piece of work through its shop career, and for our illustration we will take the main spindle of a lathe. The person in charge attaches the tag, as in Form 2, to the rough stock, which is ready for the first operation of forging. This routing tag carries all the information necessary to take the work from department to department to completion. When the work is completed the consecutive history should be shown upon the tag, which should never leave the work except to act as a requisition for piece-work contracts. Upon the tag being placed in the hands of the clerk, the contract should be made out in duplicate. The price is put upon the job and one of the contracts is returned to the foreman. The duplicate contract is retained in the office. From this contract card the time is made out on a ticket and sent to the office. also the time clerk makes entry of the time upon the back of the contract card. In the office the time is entered upon the back of the duplicate contract card. When the job is "turned in" the original contract and the duplicate must balance. When completed, the contract is OK'd. and is turned over to the office, the amount of the man's day pay is deducted, and the balance made payable. When he receives this balance he gives his receipt, as shown in Form 4. After the contract has completed its active usefulness it is returned to the clerk, to be placed in a filing envelope and filed in a suitable cabinet. Under this system two men and a messenger can take care of 25,000 contracts during a year, with all of their mass of detail.—**John H. Van Yorx,** *Eng. Mag., Vol. XXV., No. 5,* pp. 699–713.

Job No. 1750 Piece No. 80 K
Division Headstock
Location Main Spindle
Material M.S. Forging Size 4½ x 48½
Drawing No. 9546 Pat. No. 80 K No. Req. 25
Details of Oper.

Rough turn to 7/32
Finish turn - leave .008 to grind

OVER

5035.

Man's Name	Date	Time Started	No. Hours	Operations	No. Pcs.	O.K.
John Brown	2/2/03	7 Am	1	Forging	25	G.D.
James Pledger	2/9/03	2 Pm	2	Roughturn	25	F.T.
Thomas Morton	2/23/03	8 Am	2	Spacing	25	L.R.
Geo Johnson	3/1/03	7 Am	1	Finish turn	25	H.J.
				Milling		
				Grinding		
				Assembling		

OVER

FORM 2 ROUTING TAG 3¼ BY 6 INCHES, STRONG HEAVY MATERIAL TO WITHSTAND SHOP WEAR.

PIECE-WORK SYSTEM.

Gauges and Standards as affecting Shop and Manufactory Administration.

THE methods described are regarded as first steps to the introduction into an old-established factory of systematic methods of manufacture. Parts must be put through in quantities, as opposed to the old practice of putting work through in sets, by this method only is it possible to obtain the fullest advantage from the use of gauges and standards. The object of putting work through in sets was, to ensure all parts fitting into each other correctly, and to ensure units being put through in correct numbers to form complete sets. Under the new system these requirements are met by limit or other gauges to give accuracy of fit and to ensure interchangeability, and by a system of storage which gives for each unit a maximum number to be stocked. The use of gauges and standards is an absolute necessity to the system, in order to secure uniformity and accuracy of workmanship, the cheapening of production by specialisation of

plant, and by the application of routine methods to the production and storage of individual parts. The use of gauges and standards as influencing uniformity and accuracy of workmanship may be briefly divided into:—(1) the limiting of travel of cutting-tools by the use of stops or micrometer adjustments in a lathe or other tool, or by fixed points on templates or gauges in planing, slotting, or milling machines; (2) the use of limit-gauges to ensure the correct fit of any two units which come together in the formation of a fitted article. By the use of limit-gauges, details or units can be produced in special tools separately and correctly without reference to any other part. Standards facilitate the use of special chucks and fixtures in which a casting or forging is readily set by locating points, and clamped quickly by means of eccentric clamps, knurled headed screws, or other similar means. Drilling, too, on circular or rectangular surfaces, should, where possible, be standardised, and drill jigs should be used as a means to accurate reproduction. Considering the influence of the use of gauges and standards on the application of routine method to the production and storage of individual parts or details, the author says that a system of storage is introduced by means of which each individual part or detail has a symbol for type, and a number for size, a maximum and minimum stock being fixed. A stock-card is kept in a slide in each partition in the stores, incomings and outgoings being entered on the card, and an order issued when the minimum is reached; in this way stock of parts is automatically kept at its right level.—**H. J. Marshall,** *Proc. Inst. C.E., Vol. CLIV., Sec. III., 1903.*

Name	Geo Johnson	Pec. No.	T 80 K		
Division	Headstock	Job No.	1250	Cont. No.	8542
Operation	Turning to finish after being roughed, cuts on five bearings to grind, cuts thread leave .008 to grind.				
Day Rate	250	Pec. Rate	345	No. Mchs.	1
No Pecs.	25	Price	$2.00	Total	$50.00
Com.	T.O.M. 3/17/03	Foreman's O.K.	F.T.		
Fin.	J.P.M.	Inspector's O.K.	R.J.		
Remarks	Stock in excellent condition				

3034.

Date	Hours	Amount	Hours	Amount	Date		
3/17	10					Contract	50 00
18	10					Day Pay	36 25
19	10					Balance	13 75
20	9						
21	10						
23	10						
24	10						
25	10						
26	10						
27	9						
28	10						
30	10						
31	10						
4/1	7		145	36 25			
2							

FORM 4. RECEIPT CARD, SIGNED AND RETURNED BY THE WORKMAN IN EXCHANGE FOR THE AMOUNT CALLED FOR THEREON.

PIECE-WORK SYSTEM.

Preparation for Factory Management.

In this paper the author presents a definite programme for business training. Formerly, the line of promotion in industrial business was from the clerk or stenographer to the high administrative positions; now, and still more in the future, the trained engineers are selected for these positions, for their sounder and practical method of thought. Therefore, the education of engineers should in some measure prepare for this. Many old standard courses of study have died away; thermodynamics has only recently been rescued from unpractical abstruseness. More studies might be found that could be omitted or abridged. Instead of them, give training in business ideas, instil principles of cost-keeping into the student, give him an idea of shop-practice and business methods. Make the seniors the shop-foremen over the younger students, have them work out in detail the cost of one or two machines that are built in the shop —**Prof. H. Diemer,** *Am. Soc. for Testg. Materials, Report Eng. News, Vol. L., No. 2,* pp. 34-35.

The Premium System of Remunerating Labour.

This is a critical survey of the advantages and disadvantages inherent to the various modifications of the Halsey system, made with a view to obtaining a clear idea as to the suitability of each of them. The conclusions arrived at for the original Halsey system (premiums increasing from zero up to a maximum value) are as follows:—The higher the ratio of payment, the more time should be saved from the fundamental time, in order to arrive at equal costs per piece. The lower the wages, the lower is the profit per hour with equal time savings—*i.e.* equal consumption of time—and the lower is the cost of manufacture for equal consumption of time. The same rules are true of the Rowan system, premiums increasing up to a maximum value, and then falling down to zero. The injustice inherent to both these systems is avoided by Isaac Ross's system, which appears

to be the most advantageous from the workman's point of view. The most rational system, in the author's opinion, is his own, where, for different rates of payment and equal times of manufacture, the profits per hour are approximately equal, and the cost per piece, with equal manufacturing times, is the lower as the rates of payment are lower. The author, however, draws attention to the necessity of choosing the most convenient system in each special case, though all of them have so far proved satisfactory in practice. —**B. Schiller,** *Zeitschr. Ver. Deutsch. Ingen., Vol. XLVII., No. 34, Aug. 22nd, 1903,* pp. 1207-1216.—*A. G.*

The Organisation, Maintenance and Management of a Modern Pattern Shop.

FOR a pattern shop employing 25 men, the form of organisation recommended is as follows:—(1) A mill gang, which shall get out rough timber, plane and saw, but not dimension; (2) Dimension gang, which shall put the mill gang product into lengths, shapes, and fitness; (3) Assembling gang, which shall build the preceding product into pattern form; (4) Finishing gang, which takes care of rounds, fillets, dowels, draw and rapping plates, sand-papering, etc.; (5) Varnishing gang, which also affixes symbols, lettering, etc.—**Jos. Leon Gobeille,** *Journ. Amer. Foundrymen's Assocn., Vol. XII., Part I., June, 1903,* pp. 135-145.—*P. L.*

WATER AND SANITARY.

Experimental Treatment of Sewage Containing Trade Waste at Huddersfield.

HAVING described experiments conducted during the past five years at the Huddersfield sewage purification works and their results, the author states that in conducting these experiments he has not been biassed in any way. He did not pin his faith to septic tank, chemical treatment, contact beds, or trickling beds, and he has brought forward to the best of his ability the defects and the merits in each case. All artificial processes are far from being perfect. Each has its defects, and it is only by careful investigation that it is possible to determine the system to be applied to any particular locality. It is now generally admitted that similar results may be obtained by the use of an open septic tank, as with a closed one. Where the septic treatment of sewage is adopted, a very much larger tank accommodation is necessary, the sewage having to remain in the septic tank twenty-four hours, more or less, whilst five or six hours is sufficient for chemical treatment and sedimentation. The larger tank capacity necessary in the septic process has the advantage of allowing a mixing of the strong day sewage with the weak night sewage, which is of great importance under the existing conditions. Should, however, the recommendations of the Royal Commission become law, and the manufacturers be compelled to allow their waste to flow into the sewers over an extended period, then the septic tank would have but a slight advantage over sedimentation tanks. From the statements made by various authorities on sewage treatment. it appears that the preliminary anaerobic or septic treatment of some sewages induces a more vigorous action in the beds used for their subsequent purification. Taking into consideration the cleanliness of chemical treatment, or the sedimentation of sewage under aerobic conditions, the reduced tank accommodation necessary and the slightly improved condition of the effluent for subsequent purification, the anthor is of the opinion that these should not be overlooked in making comparisons with the advantages of the septic process. With regard to the form of beds used for the purification of the tank effluent, the contact bed has now a most serious rival in the trickling bed, the wonderful amount of purification effected by the latter bed necessitating less than half the area of land, and thus compensating for the extra cost of the material.—**K. F. Campbell,** *Jnl. San. Inst., Vol. XXIV., Bradford Congress, July, 1903.*

Sterilisation of Drinking-Water by Ozone.

THE authors record some experiments made by themselves and other scientists in Martinikenfelde, it being shown that ozone will destroy the bacilli of typhus, cholera, and other infectious diseases. Analogous experiments by Proskauer and Schüder in Schierstein Waterworks on other microbes related to pathogenic bacteria, gave as favourable results. In connection with their work on the problem in issue the authors give full particulars as to the technical resources that permitted them to obtain these results, describing the installations at the Wiesbaden and Paderborn Ozone Waterworks, the former affording an output of 250 m.3, the latter 60 to 80 m.3. Some model types of technical ozone apparatus are produced, the economy of this means of sterilisation being discussed on some practical cases.—**Proskauer** and **Erlwein,** *Elektrotechnischer Anzeiger, XX. No. 48,* pp. 1474-1475.—*A. G.*

The Practical Value of Presumptive Tests for *Bacillus coli* in Water.

THE status of the test for *Bacillus coli* in the sanitary examination of drinking water at the present time is one of great uncertainty, and yet there is no subject of more practical importance. The uncertainty is caused in part by the fact that there is no one method generally accepted by which the presence of this organism in water is determined. Each bacteriologist has his own way of isolating it and studying it in pure culture, and the results obtained by these different methods fail to agree. The bacillus itself, in spite of an immense amount of study, is one which cannot be always recognised by the

usual methods employed. After full discussion of the subject the author arrives at the following conclusions: (1) The methods necessary for the certain identification of *Bacillus coli* in water involve technique so complicated and so time-consuming that they are not practical as working tests in connection with the supervision of water supplies; (2) the fermentation of dextrose broth, as first suggested by Dr. Theobald Smith, furnishes the most rapid and most practical test for the presence of *Bacillus coli* in water; (3) the extension of this test to cover different quantities of water in the same samples, thus making the test quantitative as well as qualitative, greatly enhances its value; (4) *Bacillus coli*, if not itself widely distributed in nature, resembles certain common bacteria, in all points covered by the usual tests, to such an extent as to throw doubt upon the use of this organism as a conclusive test for fœcal contamination; (5) whether or not *Bacillus coli* is solely an intestinal germ, the presumptive test described above is a useful test to determine the sanitary quality of water, and is one which gives results that agree well with chemical and biological analysis.—**Geo. C. Whipple,** *Tech. Qtrly., Vol. XVI., No. 1, March, 1903*, pp. 18-31.

MISCELLANEOUS.

Raising Water by Compressed Air.

In considering the advantages of this system, it must be emphatically stated at the outset that economy is not one of them. So far as it is possible to arrive at any comparison at all, the consumption of fuel with an air-lift plant will be at least three times as much as with an ordinary pump general excellence and cost. There are, however, of an equal standard of many circumstances under which the use of compressed air for lifting water is more than justified, and where it may prove the only solution of an otherwise insurmountable difficulty. The following cases may be accepted as typical: (1) For temporary use in testing a well or boring, or in freeing a new boring of floating dirt, sand or debris; (2) for permanent use where the water is derived from sand or gravel beds, and the sand cannot be entirely shut off from entering the boring; (3) in many cases the use of an air-lift plant will avoid the necessity for sinking an additional boring, and in others the hours of pumping can be reduced; (4) in cases where time is an important element, a simple air-lift plant can be installed much more quickly than an ordinary pump; (5) the initial cost of small air-lift plants is decidedly less than that of an ordinary engine and pump; (6) where water is derived from a number of borings or wells in the same neighbourhood, a single air-compressing station will serve all the borings.—**P. Griffith,** *Proc. Inst. C.E., Vol. CLIV., Sec. VI, 1903.*

The Corrosion of Metals in Sea-Water.

In the first part of this paper the behaviour of nickel-copper is investigated, materials with percentages as high as 20 or 42 p.c. of nickel showing a strength comparable to that of ingot-steel. These alloys in the heated state are forgeable, whereas they may easily be worked with cutting instruments in the cold state. Their resistivity with regard to sea-water proved satisfactory, the alterations being less material on being combined with other metals than when exposed to its action in the isolated state. When combined with iron, nickel-copper is practically protected against the influence of sea-water, &c. Alloys of zinc, copper and nickel, such as German-silver, &c., cannot be worked in the warm state. Zinc-copper alloys in sea-water are affected to a higher degree than any other copper alloys. In addition to the cross-section being diminished, a corrosion of zinc from the inner parts is noted. This, however, is observed only in the case of percentages of zinc upwards of 24 per cent. By adding nickel, this internal corrosion may, however, be practically prevented. As regards the losses in weight of metals in sea-water, the author gives a table recording the losses observed in the course of 12 months on a series of metals. When in metallic contact with iron, the e metals are practically safe against the action of sea-water, whereas the iron itself shows at the same time a correspondingly higher loss. Similar protective effects are noted among the various copper alloys themselves Such protective effects are even observed, if instead of a direct contact, both metals are in metallic connection by means of a wire. Zinc plating will protect copper only for a short time, the copper being still more corroded, after the zinc has been decomposed. In a further paragraph of this paper the corrosion of copper tubes of vessels is investigated, it being inferred that these phenomena are due to the electric current, as produced between the copper and its oxydation products. The author recommends using copper holding about 0·5 per cent. arsenic. The point next investigated is the influence of phosphorus on the resistivity of iron with regard to sea-water. The principal results obtained in this connection are as follows: Out of two different kinds of iron with different percentages of phosphorus which were in metallic connection when immersed in sea-water, the iron richer in phosphorus would be more or less protected, whereas the other was correspondingly more attacked. In a practical case recorded by the author, the loss in weight of the iron poorer in phosphorus was about three times greater than that undergone by the other specimen. The smaller the surface of the iron poor in phosphorus, as compared with that of the richer material, the greater is its corrosion. These results will account for the fact that welded-iron as a rule resists corrosion better than ingot-iron. The action of nickel is quite similar to that of phosphorus, the protective effect being very material even in the case of only partly immersed plates.—**Diegel,** *Dingler's Polytechn. Journ., No. 318, Aug. 22, 1903*, pp. 539-540.—*A. G.*

SUP

WORKSHOP PRACTICE.

This supplement is set apart for the description of new tools and appliances, and for discussion of matters relating to Works Management, Tools, the Machine Shop, Foundry, Pattern Room, and General Practice, both Mechanical and Electrical. It is of prime interest to Works Managers, Foremen, etc., from whom contributions, which are paid for, are cordially invited.

Gas Engine Repairs.

In replacing a worn-out cylinder liner and piston in a gas engine of moderate size, a little care and attention on the part of the mechanic in charge of the job will bring the efficiency of the engine up to its standard. Generally the makers of the engine supply all duplicate parts that will be required—*i.e.* cylinder liner and piston; one set of T-headed bolts for liner; one set of asbestos liner-packings. Having drained the water from the cylinder jacket, examine the gear wheels which drive the side shaft, being sure that the teeth are marked, so that they will come together in their old position on being replaced; the shaft may now be removed, and the piston pipes, etc., stripped off the engine. Next mark the cylinder and bed with a sharp chisel, so that it can be put back to the mark when finished. A departure from the original position throws a strain on the side shaft, which often causes the breaking of the gear wheels. All being arranged beforehand for lifting, the cylinder may now be lowered, and the work of getting the liner out commenced. The method adopted greatly depends upon the design of the liner, also on the deposit of lime, caused by the hardness of the water, the writer having known cases where the hardness of the deposit necessitated the liner being drilled out. Should the bottom of the liner have a shoulder, as shown in Fig. 1 *A*, a plate and bolt may be used, being careful that the bottom plate is not too long, or the cylinder end may be broken by the plate's becoming jammed. Pieces of steam pipe cut to a dead length make good supports, *BB*, for the top plate, which may be made of flat iron bolted together and placed on edge. Many makers design their liners to be flush with the bore of the combustion chamber, this being the better plan, for it leaves no ridge for the deposit of carbon and gives the piston clear access to expel the burnt gases. It will be seen in Fig. 2 that a stiff steel-bar is placed through the holes in the top end of the liner which the makers provide for this purpose, the drawing screw having an eye through which the steel bar passes, the pressure being applied on the cross plate as in Fig. 1.

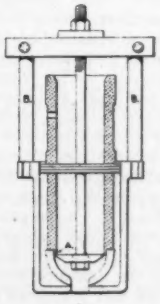


FIG. 1.

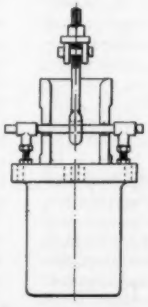


FIG. 2.

FIG. 3.

GAS ENGINE REPAIRS.

Should this method fail to move the liner, place an ordinary steam T-piece over each outer end of the bar, and with two set-screws apply more power by tightening up the nuts. Having put as much strain on as possible, lift the cylinder off the floor by a sling on the liner, and with a heavy hammer give the top of the liner a few sharp blows ; it will be found on once making a start there will be no further difficulty. After cleaning the cylinder the new liner may be tried in, and the faces well ground together with emery-powder. This is rather a slow job, but as the joint depends upon this face it must be a good surface. Then try the front end of the liner in the engine bed to see that it is quite free. Now sling the liner up vertical and get the cylinder directly underneath, so that the liner and bolts can be lowered into their places and tightened down ; this prevents any difficulty with the bolts fitting when the packings are on and the liner is finally lowered. Wood packings will be found convenient for the cylinder to rest on while getting the bolts through. Having tried the liner and bolts they should be marked to their places, and, everything being well cleaned, the asbestos ring may be secured to the liner with a little india-rubber solution. The top rubber or expansion joint being placed in the groove and all bolts in position, the liner may then be lowered. Care should be taken to get as much of the rubber joint in as possible by pressing it with a thin piece of steel while the liner is being drawn down by the bolts. The cylinder may now be turned down and the bolts wrapped with a little hemp and white-lead. It is then ready for marking the oil-hole off in the liner and must be slung on the engine bed, making sure at the same time that the chisel marks come together. Having drilled and tapped the oil-hole, the liner must be grooved like the old one ; now replace the cylinder, and, having tightened up all bolts, and the pipes being coupled up, the water may be turned on. Having so far completed the cylinder, the small end-brasses must be beded on the piston pin, and the connecting-rod tried for being linable with the piston. For this purpose, place the latter on end with the connecting-rod upright (two pieces of wood will hold it in position), and place a straight-edge up the side of the piston. See that the brasses are against the side in the piston next to the straight-edge, Fig. 3, measure the distance between the top of the rod and the straight-edge ; try the other side in the same manner. Both measurements should correspond ; if not, throw the rod by filing the back of the brass the way it requires to go. The piston and connecting-rod being coupled-up, and everything being ready, the engine may be run at a slow speed for an hour or so, plenty of oil being kept on the piston. After that time the speed may be increased, a brake being applied to the fly-wheel (care being taken not to over-heat the rim), or a few of the machines in the factory will assist in applying enough load to keep the engine on the gas every time. Having closed the bottom water-valve so that a very slight flow is obtained, just enough to keep the cylinder full when at boiling point, tighten up the liner bolts and flanges. Now boil upagain,keeping the engine well on the brake, and giving it plenty of oil ; and after having run at boiling-point for half-an-hour, open at full the bottom water-valve, keeping the engine still on the brake, thereby cooling the liner on the piston. Should the piston knock while under this test the engine must be instantly stopped or it will cause the piston and liner to seize, the piston must be taken out and the sides and junk rings well eased with a second cut-file to allow it to bed on the bottom. A tight piston in a gas engine will give endless trouble and also increase the gas consumption to a large extent. If a diagram be now taken with all valves in good order the engine will be found to come up to the original horse-power.

H. T. M.

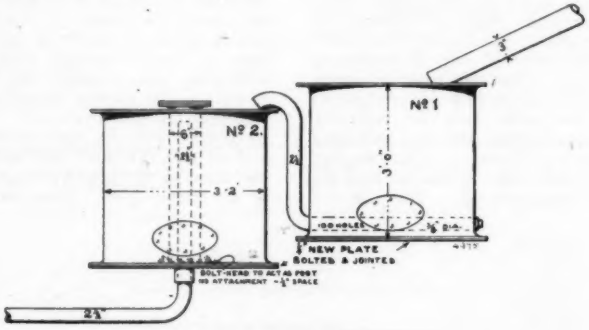
Oil Filters for Water of Condensation.

The disadvantages arising from the greasy nature of water of condensation obtained from exhaust steam—when used as feed-water for boilers—are so great as to practically preclude its use in many cases. And where it is used without an attempt being made to extract the oil, the deleterious effects on the boilers are familiar to all engineers. The illustration shows a very effective filter which was made at a trifling cost for a cement works with which I am connected and has proved a very effective arrangement. The filters are made of old boiler flue rings and worked in pairs. The condensed exhaust steam enters the first filter, which is fitted with rough coke through which it percolates. On reaching the bottom it rises through small holes in the underside of the 2½-in. W.I. pipe and finds its way into filter No. 2. This second filter is fitted with very small coke which has had the dust screened out. The water passes through this to the bottom, whence it rises in 6-in. C.I. pipe and overflows down internal standpipe away to the hot well. During the passage of water through the coke all grease

is extracted. The internal stand-pipe of second filter must be about 9 ins. above the level of water in hot well ; the 3-in. C.I. pipe from air-pump should run downhill to drain. The intervals between removing coke and replacing with fresh vary of course with the quantity of oil in the water. The fitting up is clearly illustrated. A. B.

Temporary Running of a 4-ft. Boring Lathe.

The lathe was driven by double countershafts, one above the other, these in turn being driven from the main shafting. The other morning, shortly after starting, the whole of the upper set of countershafting came down with a tremendous crash, smashing the pulleys to pieces. This was caused, it was found later, by a flaw in the shafting, which was new, and owing to an extra strain it snapped. The work in hand—boring the faces for the magnets on the carcase of a 150-kilowatt generator —was a "rush" job, and it was of the utmost importance to go on with it as soon as possible. Of course, new countershafting could not be made and fixed for several weeks, so we got out of the difficulty as follows:—It was decided to run the lathe by means of an electric motor temporarily fixed at the back of the lathe. The only motor available, however, was a 10-h.p. 400-volt machine running at 800 revolutions per minute. This was, of course, too high a speed by far at which to drive the lathe, even if the belt were run direct from the shaft, in which case there would have been too much slip, and it was therefore decided to reduce the speed by electrical means and bring it down to 300 revolutions per minute. This was accomplished by exciting the fields at 460 volts and the armature at 150 volts ; this gave the required 300 revolutions per minute. A shunt regulator was put in circuit with the motor field, which allowed the speed to be increased at will. The power was obtained from the shop motor, which is only used to drive when the engine is not running, being run as a generator, and generating 150 volts. A resistance was placed in the field circuit, which made it possible to lower the voltage, and so decrease the speed of the motor. The latter was connected up with the starting switch in a convenient place for the turner, who could start and stop at a moment's notice, and also regulate the speed whilst running. This arrangement has now been working satisfactorily for some weeks. R. V. C. Brook.

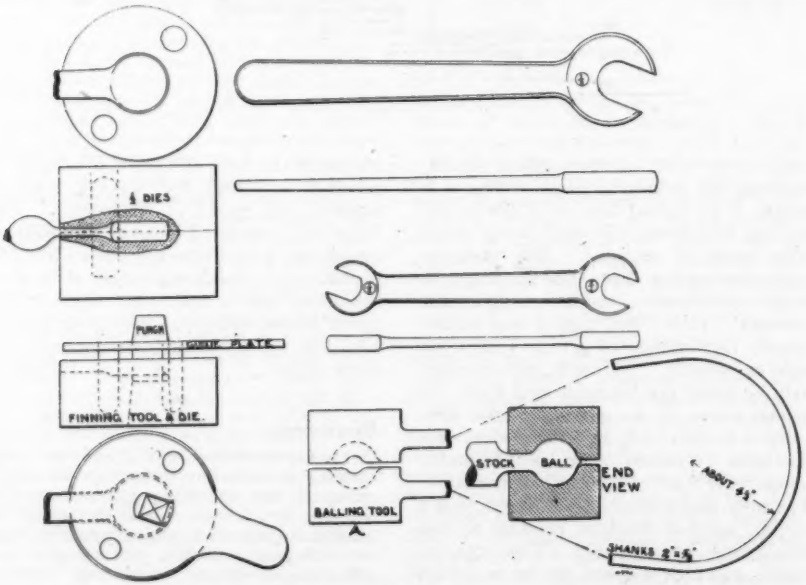


OIL FILTER.

Spanners.

A well-proportioned, handy, and convenient spanner is, according to my experience, the exception, not the rule ; I mean one that will not jib at a nut, spread at the jaw, or attempt to perform a surgical operation upon one's fingers. Such a tool is, after use, affectionately rubbed down, and carefully placed on its accustomed hook in the spanner

rack. Ill-formed, weak spanners are time wasters, and continually require renewal; and where these are forged singly, as required, they are an expensive nuisance to the shop management. A few years ago the writer designed a set of spanners and tools for making them; and although it is generally considered a subject too trifling for serious thought, no work has given the writer more genuine satisfaction. A sample of a single-end and a double-end spanner is shown. Double-ends are useful up to $\frac{3}{4}$-in. size, single-ends from $\frac{5}{8}$-in. upwards. Tools required for each size—one balling tool, one pair of top and bottom stamping dies, one finning and punching die, with punch and guide-plate. A balling tool is shown at *A*, and is the ordinary form of swage or clam found in any smith shop that possesses a steam hammer. To make—turn up a ball and shank of the required dimensions, heat the balling tool ends, and stamp on to the blank: the corners should be well rounded off, as shown, to prevent galling. The dies may be either cast iron with steel faces, or steel throughout; the latter is the more costly, but infinitely more satisfactory. The dies may be forged with circulars or squares; after forging chuck in the lathe, and recess for half the thickness of spanner-head. The die will require two settings, the head being formed by two circles; the shank piece is then shaped out, and guide-pieces fitted to bring the two halves accurately together. It will be seen that these dies do not require much hard labour. A piece of lead is then stamped in them to prove their accuracy. In stamping a portion of the metal is squeezed out between the two dies, and adheres to the spanner. To cut off readily a finning tool is a necessity. This is made in exactly the same manner as the dies, with this difference—the finning tool is recessed the *full* thickness of the spanner. This tool also acts as a die for the punch that cuts the piece out to form the jaws, by having a hole cut through it, the top side allowing a little clearance for the punch, and enlarged below to allow the burr to drop readily. A guide-plate for punch is made about $\frac{3}{8}$ in. thick, with two pegs riveted in, slotted to receive punch, which should fit accurately over the hole in die. The steel punch should be sufficiently long to stand above guide-plate. A neat finish to the spanner is made by stamping the size, as shown. This was done by drilling $\frac{1}{2}$-in. dia., cutting the size on the end of $\frac{1}{2}$-in. dia. steel peg, and driving into die, allowing the peg to project above bottom of die about $\frac{1}{32}$ in. After tools are proved



SPANNERS.

correct, harden. To make spanners: Heat all tools just too warm to handle. Take diameter of steel required for ball, find length of material required, mark with cold set. Heat to a good lemon colour, and turn in balling tool — swages to meet; flatten the ball slightly, place in stamping tools, and bring tools together. There will be little fin if balling swages are right size. Remove and place in finning tool, fin, put guide-plate on and punch, removing plate after first blow; this preserves plate. Remove and re-enter in stamping tools to square up edges. Cut off at mark, and draw out shank if for single end; if for double end, back to fire and repeat operation. To draw out middle of double ends a pair of flat swages are required, on account of width of hammer-blocks. The punch should be about $\frac{1}{8}$ in. under finished size, the edges of jaw being drawn down slightly in punching. Put on slotting or milling machine with tool full width; then to emery wheel; harden. The appended table shows the diameter and length of material required for the several sizes.

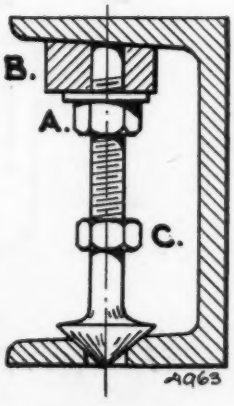
WORKS MANAGER.

Dia. of Bolts.	Dia. of Ball to form Swages.	Dia. of Shank.	Dia. of Material.	Length of Material.	Class of Spanner.
$\frac{3}{4}$"	1"	$\frac{1}{2}$"	1"	4"	$\frac{3}{4}$" single.
$\frac{7}{8}$"	$1\frac{1}{2}$"	$\frac{5}{8}$"	$1\frac{1}{2}$"	$4\frac{3}{4}$"	$\frac{7}{8}$" and $\frac{3}{4}$" double.
$\frac{3}{4}$"	$1\frac{3}{4}$"	$\frac{3}{4}$"	2"	5"	$\frac{3}{4}$" and $\frac{7}{8}$" double.
$\frac{7}{8}$"	$2\frac{1}{8}$"	$\frac{7}{8}$"	2"	5"	$\frac{7}{8}$" single.
$\frac{7}{8}$"	3"	$1\frac{1}{8}$"	$2\frac{1}{4}$"	6"	$\frac{7}{8}$" single.
1"	$3\frac{3}{8}$"	$1\frac{1}{4}$"	$2\frac{1}{2}$"	6"	1" single.

Countersinking Girders.

The illustration shows another improvised method of countersinking holes on the inside of channel and *H* section girders, especially where drilling through the top flange is not permissible. The arrangement consists of a countersink bit having a screwed shank. The feed is obtained by the nut *A* bearing against the packing *B*, inserted between it and the top flange of the girder, the bottom nut *C* forming the purchase for a spanner by which the drill is turned.

H. L.



COUNTERSINKING GIRDERS.

Another Way of Modernising an Old Engine.

Two years ago I had occasion to overhaul a flour-mill plant at Leith, which was driven by an old beam engine (compound), originally designed to work on a pressure of 40 lbs. per sq. in., but, owing to deterioration of the boilers, the pressure was reduced to 30 lbs., the boiler being close to the engine, 20 ft. The new boilers were put in at another mill, 240 ft. from this old beam engine; there was to be a new compound Corliss set put in the new mill, and supplied from these boilers at 100 lbs. steam pressure, and as there was an old flue which led the smoke from the old mill into the same engine as the two new boilers at the new mill, my proposal was to utilize this flue as a conduit for a steam pipe to feed the old beam engine. A pipe was led, and a reducing valve inserted within 10 ft. of the engine, reducing from 100 lbs. to 40 lb., with the result that the engine went much steadier, was capable of doing more work, and dispensed with the obsolete boiler and its cost of maintenance.

J. C.

An Improved Trammel-Head.

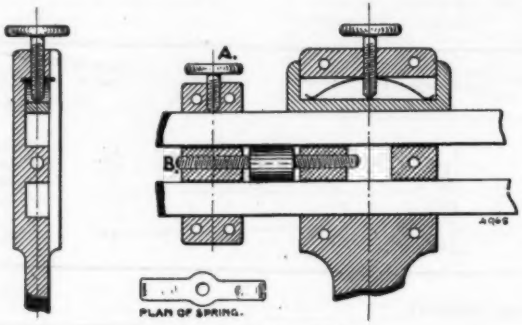
The sketches show an improved form of trammel-head suitable for marking out plate-work, etc., where great accuracy is required. The usual form of head, when placed on a line or on the division of a rule, springs upon being tightened, causing frequent readjustments, which, in exact jig and template work, become most tedious, besides endangering the accuracy of the work. The feature of the improvement is the introduction of a spring in the head, so that it is always square with the lower edge of the bar. The bar is shown slotted out at one end, in order that a fine adjustment (at *A*) may be introduced. This consists of a differential screw having a central knurled head, the right and left-hand threads of which engage in movable block *B* and trammel head. The illustration shows the whole of the details necessary for construction, so that all constructional detail can be got from them, no further explanation being necessary.

A. C. K.

Adjusting Brasses.

An easy and reliable method of adjusting brasses, where—on account of hurry or other cause—leads cannot be taken, is as follows :—Take all liners out, and nip the brasses lightly unto the pin, care being taken that each side of keep is an equal distance apart (which may be done with callipers or straight-edge), then fill in with liners a good fit. Slack back and insert thickness of liners thus found, and also add 1 tin liner extra for each side, and tighten up for good. I have found this to give very good results, always, of course, providing the brasses have not run long enough to need backing off from the sides.

A. B.



AN IMPROVED TRAMMEL-HEAD.

QUESTIONS & ANSWERS.

Lining up Bearings.

When laying out electric generating plant in which large direct-coupled engines and dynamos are employed, what is considered the best means of lining up the outside bearing, and is this done before or after the engine bed-plate is bolted down? R. L. H.

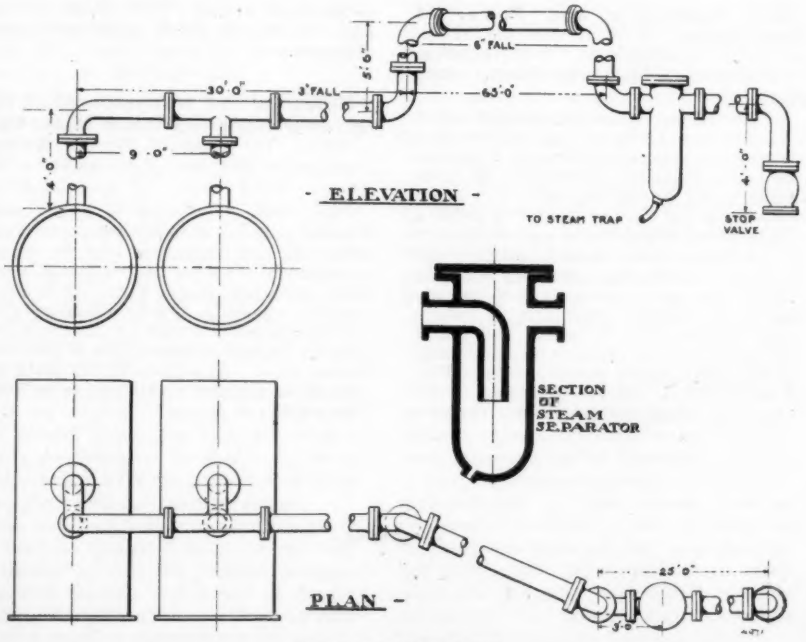
Electric Cranes.

In practice, which type of electric gantry crane is found best—those fitted with separate motors and controlling gear for each action, or those fitted with only one motor? In the former case the motors may be overloaded for a short time, as they are only used intermittently. The electric connections are, of course, more numerous, and the initial cost is greater. In the latter case the mass of gearing is enormous, and numerous clutches are required. Also the motor is kept constantly running in large works. Which is considered the better means of conducting the current to the crane, by trolley wires or by the third-rail system? R. L. H.

REPLY TO S. F.

Water in Steam-Engine Cylinders. Draining Steam Pipes.

A correspondent, S. F., asked in a recent issue of FEILDEN'S MAGAZINE



WATER IN STEAM CYLINDERS.

how to get rid of water in steam-engine cylinders, at the same time showing a general arrangement of boilers, steam pipes, and engine cylinder, etc. I beg to submit the present case which came under my notice about three years ago, and is about the worst I have had to deal with in a large and varied experience. The engine in question was a 350-h.p. Corliss high-pressure and slide-valve low-pressure cylinders. Boiler pressure 100 lbs., steam pipes welded steel only ¼ in. thick, with loose flanges; they were in a very exposed position, and the design of the building necessitated their being taken in the direction shown in the sketches, which also give the leading dimensions approximately. When we started the new engine the low-pressure cylinder was flooded with water—the 1¼-in. syphon pipes at each end of the cylinder were discharging full bore all the time the engine was running; it soon became evident that we should have to treat the steam before it reached the cylinder; so we made a separator, as shown, and fixed it in the range of pipes at the last bend outside the engine-house, with a 1¼-in. drain-pipe at the bottom, coupled to a Geipel's steam-trap; we found this a great improvement, and the engine now works satisfactorily, with the drain-taps shut except at starting. A gauge-glass was fixed on the separator, as on a boiler, to indicate the water-level; this, however, is not shown in the sketch. The pipes were outside in the open, and had a slight fall towards the boilers to assist the drainage. The whole length was fixed up without an expansion joint, as shown, which was a great advantage, the pipes being carried up 5 ft. 6 ins. high in the centre for about 22 yds., so as not to interfere with business underneath. The elbow-joints allowed all the necessary expansion and contraction.

J. GREEN.

REVIEWS.

The Resistance and Power of Steamships.—By W. H. Atherton, M.Sc., and A. L. Mellanby, M.Sc. (The Technical Publishing Co., Ltd., Manchester, 1903.) 5*s.* net.

In this volume we find the reproduction of some articles which have appeared from time to time in the pages of the *Practical Engineer*. One of the problems presented to the naval architect and marine engineer is to ascertain what power will be required to propel a ship of given displacement and dimensions at the specified or desired speed. This question is intimately connected with the subject taken up by the authors of the present work, wherein resistance in various forms is adequately discussed, and practically all recognised methods of determining the necessary engine power are considered in detail. Those who are interested in this department of engineering will find the work of practical service. It is clearly written, and is illustrated with a number of useful diagrams.

Notes on the Management of the Gardner-Serpollet Steam Motor Car.—By G. H. Olliver. Second Edition. (London: Iliffe & Sons, Ltd., 1903.) 2*s.* 6*d.* net.

This book is intended to impart such knowledge as will enable the driver to avoid difficulties and breakdowns by the proper management of his car, and, in case of breakdown, to find out readily where the source of trouble is situated. The main features of the Gardner-Serpollet system are described, and a useful diagram of connections is given in a folding plate. As a guide to this particular type of car the handbook ought to be found very useful.